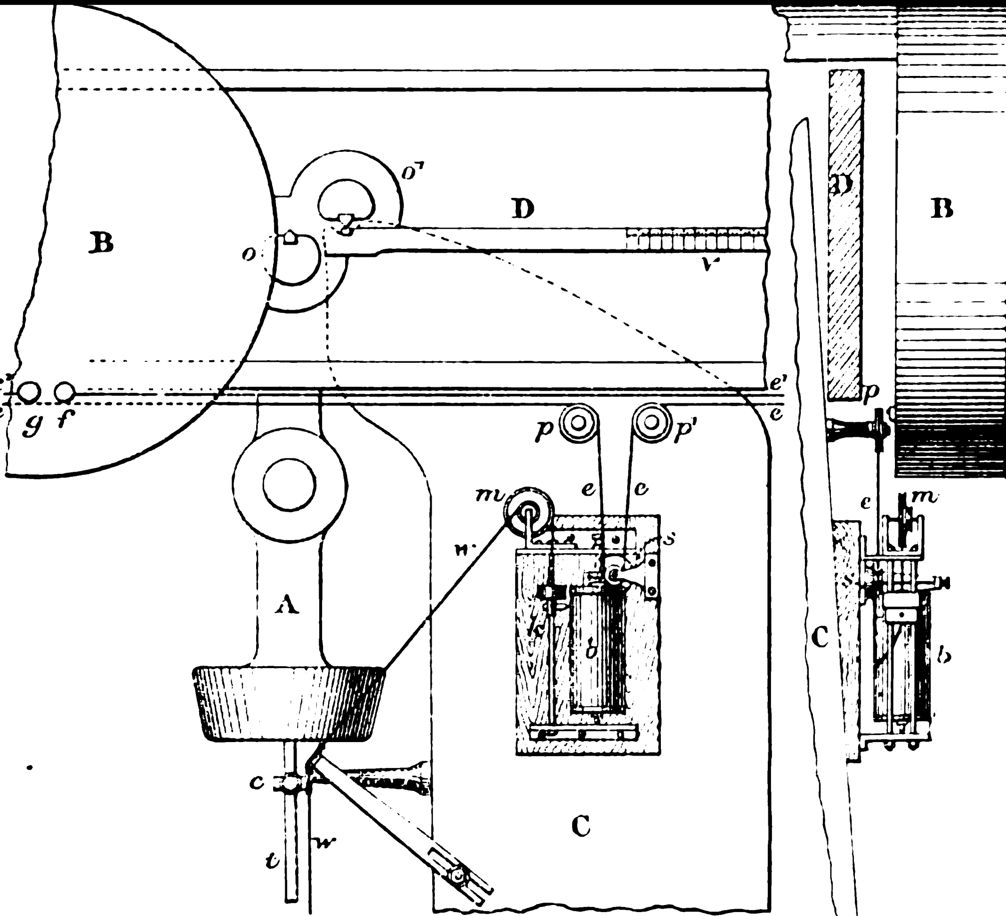

Minutes of proceedings of the Institution of Civil Engineers

Institution of Civil Engineers (Great Britain)

MINUTES OF PROCEEDINGS

OF

London, Eng. —

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. LXXXVIII.

EDITED BY

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CONTENTS.

Sect. I.—MINUTES OF PROCEEDINGS.

21 *December*, 1886, 11 and 18 *January*, 1887.

25 *January*, 1, 8, and 15 *February*, 1887.

22 *February*, 1887.

SECT. II.—OTHER SELECTED PAPERS.

SECT. III.—ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

CORRIGENDA.

Vol. lxxxvii. pp. 416–17. The statement that Mr. Bell was Resident Engineer of the Barry Dock is incorrect, Mr. John Robinson, M. Inst. C.E., having held that office since the commencement.

„ „ p. 496, lines 7 *et seq.* The quantity given as 3·37 cubic metres should be cubic decimetres. This misplacement of the decimal point, when cubed, gives rise to a thousandfold error. The volume of hydrogen compressed into a space of 90 cubic centimetres will consequently be 38 atmospheres, and not 37,000 atmospheres, as stated by the Author of the Paper.

„ „ p. 507, line 14 from bottom, *for* "fourteen years" *read* "forty years."

„ lxxxviii. p. 99, „ 18 „ „ *after* "link" *insert* "pinned."

„ „ p. 99, „ 16 „ „ delete the comma after "lever."

„ „ p. 99, „ 6 „ „ *for* "vibration" *read* "floating."

„ „ p. 111, „ 15, *for* "1 ton or 2 tons" *read* "considerable quantities."

„ „ p. 222, line 13 from bottom, the sentence should read:—"With the destructor only, to which was attached a boiler for working the engine (6 HP.) used in pumping, precipitating-machinery, &c., he formerly obtained but 20 lbs. of steam; now, with the cremator added, he obtained a pressure of 40 lbs., so that," &c.

„ „ p. 234, „ 15 from bottom, *for* "Bradford" *read* "Bedford."

„ „ p. 243, lines 19 and 20, should read:—"It was from 7 to 9 grains of lime, 1½ grain of chloride of magnesium, and $\frac{1}{16}$ grain of carbonated creosote per gallon."

„ „ p. 245, last line, *for* "be" *read* "lie"; and after "not" insert "in."

THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1886-87.—PART II.

SECT. I.—MINUTES OF PROCEEDINGS.

21 December, 1886.

EDWARD WOODS, President,
in the Chair.

(*Paper No. 2204.*)

"The Use and Equipment of Engineering Laboratories."

By ALEXANDER BLACKIE WILLIAM KENNEDY, M. INST. C.E.

SOON after the Author was appointed to his present position at University College, he had an opportunity of describing in public[1] a scheme to the carrying out of which he then looked forward. He wished to give to engineering students at the college or other institution at which they were being educated, a certain practical training. He believed that it was essential for a young engineer to obtain his practical training, in the ordinary sense of the expression, in a workshop. But the practical training of a workshop is incomplete even on its own ground, and there appeared to be plenty of room for practical teaching such as might fairly fall within the scope of a scientific institution, and which should at the same time supplement and complete workshop experience without overlapping it. In an ordinary pupilage a young engineer does not have much opportunity of studying such things as the physical properties of the iron and steel which he has to deal with, nor the strength of those materials, nor the efficiency of the machines he uses, nor the relative economy of the different types of engines, nor the evaporative power of boilers. These things, however, are only types of many others about which it is essential, not only that he should know something, but that he should form some definite working opinion. But they are all matters very closely

[1] Introductory Address delivered to the Faculties of Arts and Laws and of Science at University College, London, October 5, 1875. See Journal of the Society of Arts, October 22, 1875; and "Engineering," vol. xx. pp. 284 and 315.

analogous to those already treated in laboratory work in physics and chemistry. They involve simply the making of accurate measurements in the branches of physical science most closely related to engineering. Moreover they are useful to the student not only for their own sakes, but also as teaching the art of making experiments—or it may be simply called the art of accurate measuring—in matters relating to engineering science. They are, to a wonderful extent, suited to set the student free from the thraldom of the engineering pocket-book (making "every man his own Molesworth," as it has been put), by helping him to determine for himself, or at least to see practically how other people have determined, all the principal engineering constants, from the tenacity of wrought-iron to the calorific value of coal, or the discharge-coefficient of an orifice. Further, a healthy scepticism of uncritical generalisations, or of uninvestigated facts, is fostered by nothing so surely as by a personal and practical knowledge of what accurate experiments really are. From all these and other considerations it appeared to the Author that the kind of practical work which has been alluded to could be nowhere better given than at those educational institutions which endeavoured to teach young engineers the scientific basis of their profession, and following up this idea he gave in some detail, on the occasion to which he has alluded, a description of the function and work of an engineering laboratory. Shortly afterwards the scheme was brought before a number of the leading engineers of the country, including the present Presidents of the Institutions both of the Civil and Mechanical Engineers, and many Past-Presidents of these and the sister societies, and these gentlemen expressed thorough approval of it. Materially helped forward by this concurrence of professional opinion, the scheme was finally carried into actual practice in 1878. The idea was apparently one well adapted to the time[1]—probably it occurred to many people more or less simultaneously—for within a few years other laboratories on the same plan began to be established, and now there are in this country, either at work or in process of erection, no less than nine which may claim to be fairly well furnished, as well as some smaller ones. Indeed it seems almost to be recognized already that an engineering laboratory is an essential part of every institution training engineering students.[2]

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[1] Only a few weeks, for instance, after the Author's University College lecture, Professor Thurston gave a parallel lecture in New York in reference to the laboratory which he hoped to establish at the Stevens Institute. (Journal of the Franklin Institute, Dec. 1875.)

[2] The Author has confined himself in this Paper to the engineering laboratory

In the matter of engineering laboratories as a branch of technical education, it may fairly be claimed that England has taken the lead, instead of being, as she is so often supposed to be in such matters, in the rear. For the excellent laboratories of the Continent[1] are based upon an altogether different leading idea. They stand for the most part in more or less close relationship to technical schools, and are under the control of one of the professors. But their appliances are essentially devoted to purposes of experiment and original research by the professor himself. Engineering students see demonstrations carried on by him, but only exceptionally make any experiments themselves. This arrangement has, of course, the great advantage from the scientific point of view, that it leaves the professor much more time and opportunity for scientific research than he could otherwise have. In the case of several of the chief continental laboratories the already published results of their researches have been of the greatest possible value.[2] Where the main object, the very *raison d'être* of the laboratory and

proper, as distinguished from the laboratory of practical mechanics, which is essentially a specialized part of a physical laboratory. On the side of electrical engineering a laboratory of electrical technology may well stand side by side with the engineering laboratory here spoken of.

[1] Appendix III.

[2] The most important results hitherto published have been those of Professor Bauschinger, of Munich, who has issued, since 1871, his "Mittheilungen aus dem Mechanisch-technischen Laboratorium der K. polytechnischen Schule in München." (Munich, Theodor Ackermann.) The results of experiments in the Prussian royal testing establishments have been published, since 1883, in a quarterly journal entitled "Mittheilungen a. d. Königlichen technischen Versuchsanstalten zu Berlin." (Berlin, Julius Springer), edited by Dr. Wedding. Professor Tetmajer, of Zürich, has also published, since 1884, three volumes of "Mittheilungen der Anstalt zur Prüfung von Baumaterialen am eidg. Polytechnikum in Zürich." (Zürich, Meyer and Zeller.) Professor Jenny, of Vienna, published in 1878 the first "Abtheilung" (containing a very large number of experiments and a detailed description of apparatus) of "Festigkeits-Versuche u. d. dabei verwendeten Maschinen u. Apparate a. d. K. K. technischen Hochschule in Wien." (Vienna, Carl Gerold's Sohn.) An immense number of Bauschinger's experiments, and some of Jenny's, will also be found in "Die Eigenschaften von Eisen u. Stahl" (7th "Supplement band" of the Organ f. d. Fortschritte d. Eisenbahnwesens), (Wiesbaden, C. W. Kreidel, 1880.) Professor Belelubsky has published lately, under the title "Mechanisches Laboratorium des Wegebau-Ingenieur-Instituts," a large number of results of experiments carried out by him at St. Petersburg. Professor Gollner has published detailed drawings of his testing-machine and apparatus, with a great number of experimental results, under the title "Die Festigkeits-Probirmaschine der K. K. deutschen technischen Hochschule in Prag" (Prag, 1884), a reproduction of his contributions to "Technische Blätter" since 1877. Many of Professor Tresca's original experiments—tests of air and gas-engines, &c.—are described in the Annales du Conservatoire Impérial des Arts et Métiers. Paris, 1861 to 1873.

its apparatus, is to give to students the opportunity of experimenting for themselves, it is unavoidable that purposes of pure research should make way for those of education. Having adopted this particular idea as to the function of the laboratory, its drawbacks must be accepted as well as its advantages. Students can only in exceptional circumstances make original investigations or researches; in the ordinary course of events their experiments here, as in all other laboratories, do not give new results but simply emphasize old results on new men.

It should also be mentioned that with scarcely an exception the continental laboratories are restricted absolutely to experimental work in relation to the strength and elasticity of materials. The laboratories of Professor Schröter at Munich and of Professor Dwelshauvers-Dery at Liége seem to be the only ones in connection with any of the continental schools in which systematic experimental work connected with the steam-engine is carried on, and in these the students are expected to experiment themselves. In America the system adopted where laboratories are in existence, more nearly resembles that used in England, the laboratories of applied mechanics and mechanical engineering at the Massachusetts Institute of Technology, for example, forming together a very complete engineering laboratory. The laboratory of the Sibley School of the Cornell University, as recently enlarged, also appears closely to resemble our laboratories both in method and appliances. The Stevens Institute of Technology has also for a number of years given to its students some description of practical experimental work. An American professor writes to the Author on this matter: "The systematic instruction of students in making engineering experiments for themselves does not, as far as I know, exist in any of our technical schools. . . . It is the professor or instructor who has charge of, gets up, and directs the experiments, the students participating as assistants. It is instruction in 'experimental engineering' by example mainly. The exceptions, I believe, are in the measurement of power, the students themselves testing the engines and boilers of the shops of the vicinity."

Method of Work.

The method of teaching adopted by the Author in his own laboratory, so far as it relates to the subjects chiefly treated in this Paper, may be briefly described as follows:—In dealing with elasticity and the strength of materials, the students are grouped three or four together, and each group, after studying and sketching

the machine about to be used, proceeds to make detailed measurements of the moduli of elasticity in tension of a standard series of specimens of the principal constructive materials. Their results being calculated and plotted out, they test the *same pieces* (which are prepared so as to make this possible) in compression and in torsion, and other pieces of the same materials in bending. The bending tests also include tests of a number of different forms of beams. The less easily observed characteristics of the elastic life of materials, set, time-effect, temperature-effect, &c., are then studied, and also the effect of raising the limit of elasticity, &c. This done, other pieces of similar material are tested to destruction under the various stresses, with the special object of studying the behaviour of the materials after the limit of elasticity is passed. The work is done throughout by detailed personal measurements, and the results are both calculated and diagrammed. The whole life of each material is illustrated from time to time by the drawing of automatic diagrams, of which the students obtain copies. The work is carried on under superintendence always, but the students have actually to make the experiments for themselves from the first, learning by experience the errors into which they are most likely to fall, and the ways of avoiding them.

The method on which the engine-trials are conducted is the same in principle. The students first examine, measure and sketch the engine and its fittings. They then calibrate the feed-tank and boiler, find the discharge-coefficient under different heads, &c. These preliminaries over, the engine-trials commence, and in general two exactly similar trials, each conducted by a group of nine or ten students, are made each week. At each trial each man has his particular set of observations to make,[1] and for these he is personally responsible. At successive trials the distribution of the work is changed, so that each man may have experience in every part of it. The trial (except when fuel is being measured) lasts two hours. The remainder of the day is occupied in the working out of the results and their averages, &c. One day a week the two groups of students meet, the results are all gone over with them in detail, special points of interest or difficulty discussed and explained, and the form (A) given in appendix filled up by each student for each trial. The results of two or three trials each session are generally also diagrammed. The trials are conducted under constant personal supervision, in order that they may not be rendered useless by omissions or irregularities; but the students

[1] See engine trial forms in Appendix I., pp. 66 to 71.

are left as much as possible to themselves from the first. The Author believes that they learn to avoid errors much more quickly and certainly in this way than if any attempt were made to get the early trials perfectly accurate. During the session the engine is tested under a number of conditions, economical and the reverse, and their results are compared, the conditions of the earlier trials being repeated later on, when the students are more able to obtain accuracy than at first. Over ninety complete trials have now been made in this fashion in the Author's laboratory.

These two illustrations must suffice to show the lines upon which the Author has worked. Many other experiments are made in the laboratory, such as the testing of indicator-springs, calibration of apparatus, cement-testing, friction-tests, &c., and for many experiments the students have to make, or partly make their own apparatus. Senior students also make special experiments from time to time, the records of some of which have been published in the Minutes of Proceedings of this Institution.[1] The Author also gives demonstrations from time to time in the testing-machine on points, or with materials, having some special interest.

Fig. 4, Plate 1, shows a plan of the Engineering Laboratory at University College, London, which occupies a basement room, 90 feet by 44 feet, and 16 feet 6 inches high, in addition to the boiler house, tank-space, &c. A portion of the floor is laid in concrete floated with cement, and having a gridiron of wooden beams for bolting to. The lecture-room and cabinet occupy about half the space over the laboratory. The drawing-room, 71 feet by 51 feet, is in another part of the building, and lighted from the top.

Nature of Experiments.

The principal subjects upon which experiments may be carried on in an engineering laboratory may be thus briefly summarised :—

- (i.) Elasticity and the strength of materials.
- (ii.) The economy, efficiency, and general working of prime movers, and especially of the steam-engine and boiler.
- (iii.) Friction.
- (iv.) The accuracy of the apparatus commonly used for experimentation, such as springs, indicators, dynamometers, gauges of various kinds, etc.
- (v.) The discharge over weirs and through orifices, and hydraulic experiments in general.

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[1] See Mr. Appleby's Paper, vol. lxxiv. p. 258; and that of Messrs. Segundo and Robinson, vol. lxxxvi. p. 255.

(vi.) The theory of structures.
(vii.) The form and efficiency of cutting-tools.
(viii.) The efficiency of machines, especially of machine-tools, and of transmission-gearing.
(ix.) The action and efficiency of pumps and valves.
(x.) The resistance of vessels and of propellers, and experiments in general connected with both.

There is not yet any laboratory in existence where all these subjects are taken up—the list (which does not profess to be exhaustive) is merely given to show what scope there is for experimental work. Subject i. alone, as has been mentioned, has been generally treated in continental laboratories,[1] but American ones have covered a somewhat wider range. In this country provision has as yet been made, or is being made, in one or other of the existing laboratories, for dealing in a tolerably complete manner with subjects i. to iv. The next three (Nos. v. to vii.) are also receiving some share of attention. The last three are as yet hardly touched. This Paper will deal mainly with the first three subjects, the strength of materials, the economy of prime movers, and friction. The question of the calibration of apparatus used (subject iv.) will not require further mention than it will receive incidentally. The remaining subjects will be briefly dealt with in conclusion. The first subject inseparably connects itself, of course, with the testing-machine, the second with the experimental engine and boiler, and they will be discussed under these heads.

Experiments on the Elasticity and Strength of Materials.

The Testing-Machine.

It would, of course, be impossible here to pass in critical review all the types of testing-machines which may possibly be used. For laboratory purposes *accuracy* may be said to be the first essential for a testing-machine. Inseparable from complete accuracy is the condition that simple means exist for verifying the indications of the machine, or, in one word, for calibrating it. Sensitiveness in working may be considered as included under accuracy. Simplicity is in the highest degree desirable, but not

[1] Subjects iv., v., viii. and ix. have formed the subjects of several most valuable investigations, made by professors in various "technical high schools," but these experiments have not been carried out in any connection with engineering laboratories.

that kind of simplicity resulting from mere reduction of the number of parts, apart from their importance to the true working of the apparatus. Many simplifications which might be admissible in machines designed for use in works, and by somewhat unskilled hands, would be fatal to the usefulness of the laboratory machine, which is a scientific instrument as well as a machine, and which is presumably worked with the most skilled labour which is attainable. A laboratory testing-machine must also be readily adaptable to all sorts of conditions, for the most varied experiments have to be made in it from time to time. Further, it has to be arranged so that an experiment conducted in it may be readily made visible in all its details in demonstration to a moderate sized class of twenty or thirty men standing around. The more important testing-machines used in laboratories are all (at least in Europe) based on the constructive principle first adopted in this country by Mr. David Kirkaldy, M. Inst. C.E., that, namely, of applying the load by water-pressure, and measuring it by dead weight. For small machines, the substitution of a screw and gearing for the hydraulic ram can be conveniently made, and, of course, without any loss of accuracy. But the low efficiency of screw-gearing makes this inconvenient for machines of the size here to be discussed. Two important makers of testing-machines, however, Messrs. Fairbanks, of New York, and Messrs. Mohr and Federhaff, of Mannheim, adopt the screw for large machines, and it is used along with a ram in the Gollner machine. It is, of course, more uniform in action than a single force-pump, but has no advantage, even in this respect, over a screw-pump or an accumulator. For many years testing machines (as those of Maillard,[1] Thomasset,[2] Chauvin et Marin-Darbel[3]) have been constructed, in which the load is applied by a ram, and measured by a mercury gauge connected with a diaphragm-piston having an extremely limited motion. In the large machine designed by Mr. Emery, and now at the United States Arsenal at Watertown, a diaphragm-piston is also used, but the pressure in it, transmitted to a second smaller one, is measured by a system of levers and weights, instead of by the height of a mercury column. This plan has also been proposed by Mr. Stummer. In the absence of anything like authentic and detailed information as to the accuracy

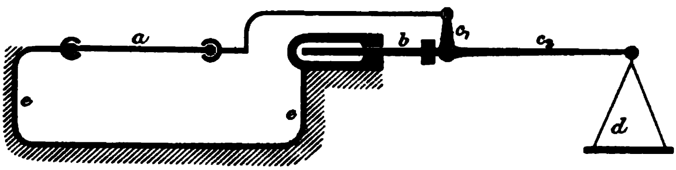
[1] "Limite d'élasticite," &c. Ch. Duguet (Paris, 1882). (Gauthier Villars), also "Les Métaux," &c. Lebasteur (Paris, 1878).

[2] "Les Métaux a l'Exposition Universelle de 1878." H. Lebasteur (Paris, 1878. Dunod).

[3] "Engineering," vol. xxvi. p. 184.

of such machines, and in view of the difficulty of calibrating them, the Author considers that the dead-weight machine is the only type as yet devised which satisfies the necessary conditions as to permanent accuracy and easy calibration, and that for machines of 40 tons and upwards, such as are generally used in laboratories, it is most convenient to apply the Kirkaldy principle already mentioned. For small machines for special purposes, it is no doubt often convenient to measure the load by some form of spring-balance, which, however, requires to be checked from time to time by weights. As the subject of this Paper is not the discussion of testing-machines in general, but only in reference to their use in scientific work, it will be sufficient to mention here those types of machines which are used for this purpose. In this connection the Werder Machine [1] (Fig. 1) may fairly be taken first, for this is

FIG. 1.



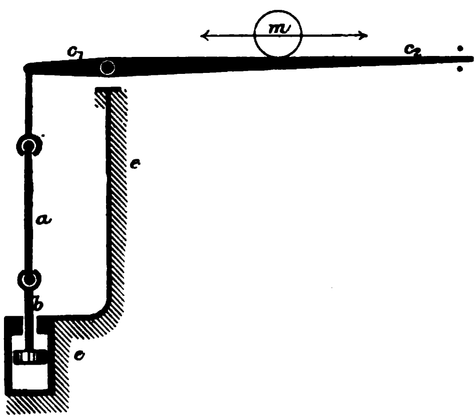
the type used by Bauschinger in his Munich laboratory since 1871, and now also employed most largely for scientific purposes on the Continent. The figure is intended (as in all the following cases also) only to make clear the principle of the machine, and not even roughly to indicate proportions or details. The test-piece a is held at one end in the frame of the machine e, and at the other pulled from the short arm c_1 of a knee-lever, to the long arm c_2 of which hangs a scale-pan d. (In the machine as constructed, the ratio of c_2 to c_1 is 500 : 1). The central fulcrum of the lever rests on the end of the ram b itself, so that the whole measuring apparatus moves along as the piece extends and the ram moves out, the arm c_2 being always kept horizontal by the help of a level. Fig. 2 shows the principle of Mr. Wicksteed's machine.[2] It

[1] See Bauschinger's "Mittheilungen a. d. Mechanisch-technischen Laboratorium in München," Hefts 1, 3, &c.; or, more completely, "Maschine zum Prüfen d. Festigkeit d. Materialen und Instrumente zum Messen der Gestalts-Veränderung der Probekörper." Munich, 1882 (Wolf u. Sohn); "Festigkeits Versuche," &c. Jenny, Vienna, 1878 (Carl Gerold's Sohn); "Engineering," vol. xxxiv. p. 324, and vol. xxxv. p. 530.

[2] Institution of Mechanical Engineers. Proceedings. 1882. p. 384.

is a vertical machine with a single lever, c_1 c_2, placed horizontally on the top of the machine. A movable monkey-weight or poise *m* measures the load, pressure being applied to the ram *b* by a screw-pump. The ratio $c_2 : c_1$ is 50 : 1. The weight *m* (in a 100-ton machine) is 1 ton, so that it balances a pull of 50 tons when at the end of c_2. To carry the load on to 100 tons, *m* is run back over the fulcrum, and a second weight of 1 ton is hung to the end

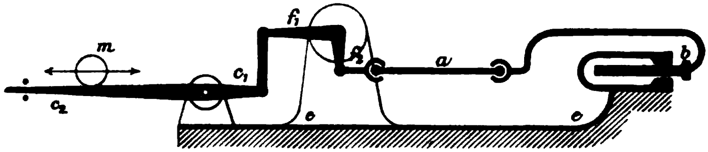
FIG. 2.



of c_2 for the rest of the test. The poise is moved along the steelyard by a screw worked by power. It runs on a little four-wheeled carriage, and is so arranged that it can be brought back (to the left in the figure) so far as to throw the whole beam into equilibrium. The pull on the test-piece is read by a vernier attached to the poise, reading on a scale fixed to the steelyard.

Fig. 3 shows the machine used by the Author in his laboratory

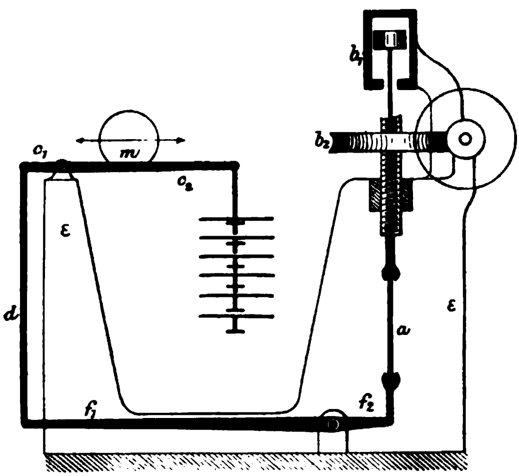
FIG. 3.



at University College. This type of machine was designed and made to meet the Author's requirements by Messrs. Greenwood and Batley in 1878, and so may be shortly referred to later on as the Greenwood machine. So far as its principle goes, it is the same as the far larger machine originally made by the same

firm for Mr. Kirkaldy (and others) under his patent. As at present constructed, it contains a number of details added by the makers as the result of their own and the Author's experience in its use. It is a horizontal machine with two levers, a knee-lever, $f_2 f_1$ (5 : 1), and a steelyard $c_2 c_1$ (20 : 1), the total leverage being 100 : 1. The load is applied by the ram *b*, and measured by the position of the poise *m* on the steelyard. The weight of the poise is variable, the carriage and hanger weighing 50 lbs. by themselves, and the whole being capable of increase, 50 lbs. at a time, up to 1,000 lbs. The Author considers that these three machines sufficiently represent the best forms as yet used for laboratory purposes; their comparative advantages and drawbacks will be

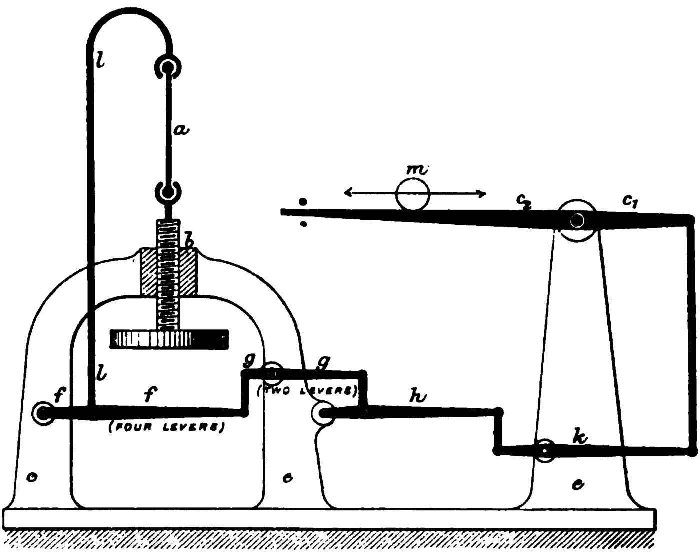
FIG. 4.



described later. It is right, however, to mention examples of other types, which in certain respects differ from these, and are more or less largely used for laboratory work. Professor Gollner's machine, used by himself at Prague, and by Professor Böck at Leoben, is sketched in Fig. 4. It is a double lever vertical machine, adapted only for short pieces, and working up to 20,000 kilos. It has two special features—(1) that both screw and ram are provided, and means for changing at once from one to the other. The screw can then be used for elastic experiments, and for maintaining a particular load on the test-piece for any length of time. (2) That for light tests the lever $f_1 f_2$ can be disconnected, and the link *d* replaced by a simple arrangement for testing

wire, &c., the machine thus being used as a single-lever machine. Mr. Daniel Adamson's machines (of which one was shown at the Inventions Exhibition) should be mentioned, although they do not happen, so far as the Author knows, to be used in laboratory work. They are multiple-lever machines of careful design, Mr. Adamson believing strongly in the use of several levers with comparatively small mechanical advantage, but with long arms, rather than fewer levers with shorter arms and greater mechanical advantage. For his 100-ton machine he uses four levers, with ratios of 10 : 1, 10 : 1, 12 : 1, and 12·5 : 1 respectively, the total mechanical

Fig. 5.

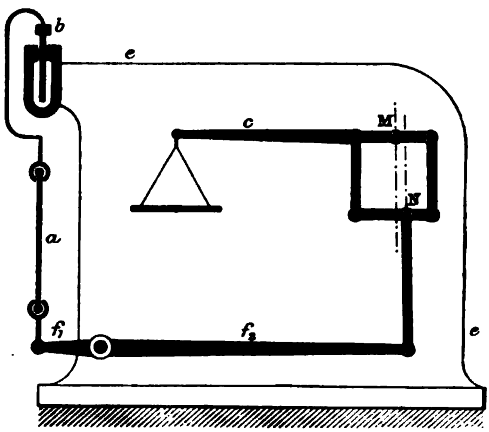


advantage being thus 15,000 : 1. The Fairbanks machine[1] is sketched in Fig. 5. It is essentially a platform weighing-machine turned into a testing-machine. The pull put upon the test-bar *a* by the screw *b* is transmitted through it to the frame *l l*, which is a platform resting on four levers, *f f*. From these it is taken by a pair of equalizing levers, *g g*, and transmitted through multiplying levers, *h* and *k*, to the steelyard c_1 c_2, where it is

[1] Wagen, Dynamometer und Material-prüfungs-maschinen in Philadelphia, 1876. J. Spácil. Vienna, 1877 (Faesy und Frick). "Testing Machines: their History, Construction and Use." By Arthur V. Abbott. New York, 1884 (Van Nostrand).

measured by a movable monkey-weight. The machine thus contains nine levers and twenty-seven principal knife-edges. The machine of Riehlé Brothers, Philadelphia,[1] contains one feature which renders it worth special mention. This machine is used in several of the American laboratories. It is sketched in Fig. 6. It is really a double-lever machine, but in order to get a large mechanical advantage for the steelyard, which involves an inconveniently small short arm, the link-work parallelogram shown in the sketch is employed, which gives the same result as if the steelyard *c* had a short arm equal to the horizontal distances between the points M and N. As a combination of link-work, the whole affair is incompletely constrained, and can only be used

Fig. 6.



accurately if it be always kept in exactly the same position; here, that is, with the steelyard horizontal. Messrs. Mohr and Federhaff (Mannheim) have arranged a testing-machine on the same principle,[2] but considerably improved in details, and have added to it a diagramming apparatus which will be mentioned further on. In Fig. 7 is shown the principle of Mr. Emery's Watertown machine,[3] on which the United States Board of Testing, and after

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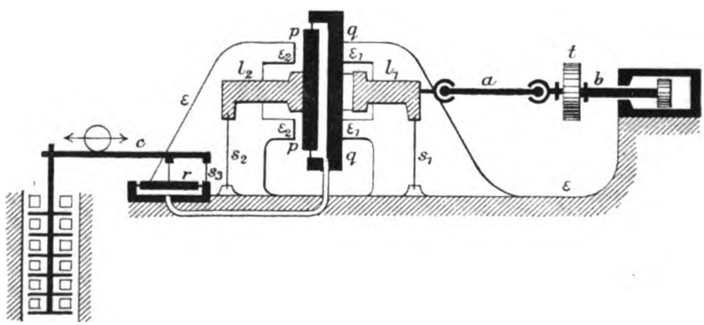
[1] See Spácil, cited above.

[2] Zeitschrift des Vereins Deutscher Ingenieure, vol. xxvi. (1882), p. 545.

[3] "Engineering," vol. xxxvi. p. 147 (copied from the American Machinist); "Report of the United States Board of Testing," vol. ii. 1881. "A New System of Weighing Machinery" (Yale and Townley Manufacturing Company), 1884. (This is an illustrated pamphlet issued by the makers, and contains the only detailed drawings published of the Emery machine.) Zeitschrift des Vereins Deutscher Ingenieure, 1884, p. 619.

it ceased to exist other United States officials, have made so many valuable experiments. With the usual generosity of an American Public Department, the results of these experiments have been fully published and made accessible to all engineers. The Author hopes he shall not be thought captious if he suggests that detailed drawings of the machine itself, and, above all, an official account of the methods adopted for calibrating its indications, and of the degree of absolute and permanent accuracy which it has been found by experiment to possess, should be published; it would add enormously to the value of the experiments which have been made upon it, and for the results of which engineers have so much reason to be grateful. The pull upon the test-piece *a* is caused, as usual, by hydraulic pressure on the ram *b*. This ram is fitted with turning-gear *t*, which, however, is said

FIG. 7.



not to be used. The test-piece *a* pulls against a frame l_1 l_2, and through it upon the back *p* of a diaphragm press-cylinder *q*, which is backed up by the portion e_1 of the bed-plate *e*. The fluid pressure is communicated by a small pipe to a smaller diaphragm-cylinder *r*, and measured by a system of levers represented by *c*. If a compression-test instead of a tension one be registered, the water-pressure is brought on the back of the ram, l_1 acts against *q*, and *p* is held up by e_2 so as just to reverse the arrangement shown in the figure. No knife-edges are used in the machine, but instead of them flat steel spring plates are employed throughout, as sketched at s_1 s_2 s_3. All absolute motions of the load-measuring apparatus, including the weighing-levers, have therefore to be kept exceedingly minute. It should be added that whereas Figs. 1 to 6 refer to machines of from 50 to 100 tons, such as have been used in laboratories, the Watertown machine is the same size (400 to 500 tons) as Mr. Kirkaldy's large machine,

and the others which have been constructed upon its lines. It is difficult to say that any one type of machine is absolutely better than all others, each has certain advantages of its own. In the case of those last described, however, their advantages appear to be counterbalanced by their drawbacks, at least for laboratory purposes. The Fairbanks machine is easily checked up to a limited load by simply putting known weights upon the platform, and testing the simultaneous reading of the steelyard. But this solitary advantage cannot be held to compensate for the extraordinary and apparently unnecessary complication of the machine, which takes nine levers to do what other machines do with two, or even with a single one. In other respects also, the machine can by no means be called a convenient one. The Riehlé type of machine is convenient, but does not appear to have any very definite advantage (even in the form used by Mohr) over a machine with a couple of ordinary levers. More could be said for it if it could be made into a single-lever machine. The Gollner machine possesses certain definite advantages already mentioned; it is rather limited in its capacity, and the test-piece in it is not so accessible as it might be, but it is of a thoroughly well thought out design. The Watertown type of machine, whatever may be said as to its ingenuity, or its suitability for very heavy loads, has the great disadvantage that its indications are not positive, and that no means appear to exist for checking them. As yet no information as to the degree of accuracy obtained in its working has been published, although remarkable statements are made as to its sensitiveness. It will therefore be sufficient for the purpose to take the three machines first mentioned (the Werder, Wicksteed, and Greenwood respectively) as types, and make a comparison between them on certain definite points.

(i.) *Accuracy.*—Supposing in each case similar workmanship and similar pressures on the knife-edges, there does not appear to be any reason for one machine giving more accurate results than another. The Werder machine is fitted with a permanent check-lever, which is probably necessary for its exceptional leverage. The other two machines can be readily checked as to zero point and as to sensitiveness. Special apparatus (of, however, quite simple character) requires to be employed for checking the leverages. In this point the Wicksteed machine is the most easily dealt with.

It is well to remember that in the checking of a testing-machine there are two points to be considered, namely, the accuracy of the leverage and the sensitiveness of the levers. The accuracy of the leverage is comparatively easily checked, for it can be best

done with small loads. The sensitiveness of the levers, which involves, of course, the frictional resistance of the knife-edges, is a different matter. It is easy to obtain at low loads, but it is much harder to arrange any satisfactory means for determining it at loads anywhere near the full load of the machine, where of course the use of dead-weight resistance is impossible. The Author does not know of any accurate experiments from which the so-called frictional resistances of knife-edges under high pressures can be deduced. Tested under a dead weight of 1,000 lbs., he found that the error due to the leverages of his machine was less than ½ lb. per ton. Pulling against the resistance of a test-piece which has not been strained beyond its limit, he finds the results given in the following Table, which records the additional pull that had to be given to the test-piece (by placing small weights on the steelyard), in order to cause the first visible falling of the steelyard. It will be seen that even although this pull includes what may be called the molecular inertia of a test-bar, as well as the frictional resistances of the knife-edges, it is a very small quantity, and its proportional value diminishes as the total pull increases. The resistances in the second column of this Table are thus to some unknown, but certainly very large, extent in excess of the mere resistances of the knife-edges. Counterbalancing the steelyard and pulling with a very fine silk thread put in the position of a test-piece, threads having a tenacity of 1½ lb. broke without lifting the steelyard; but threads having a tenacity of 2·2 lbs. easily pulled the steelyard up to its upper stop again and again without breaking. This experiment is mentioned because the Author believes that the sensitiveness of good knife-edges is often under-estimated. He made it quite recently, after more than twelve thousand experiments must have been made in his machine since the knife-edges were last touched.

Total pull on Test-piece. (= P).	Addition to pull which caused first visible falling of Steelyard. (= p).	Ratio of p to P.
lbs.	lbs.	
5,000	4·0	1 : 1,250
10,000	5·0	1 : 2,000
15,000	5·5	1 : 2,728
20,000	6·0	1 : 3,333
30,000	7·0	1 : 4,286
40,000	8·0	1 : 5,000
50,000	9·0	1 : 5,555

Trustworthy experiments on the sensitiveness of different machines at various loads, though much to be desired, at present do not seem to exist; but certainly the probable error of any one of the three is far less than the probable difference even between two pieces of the same material cut from the same bar.

(ii.) *Application of Load.*—In the Werder machine the absolute weights dealt with are smaller than in either of the others; in the Wicksteed larger. The absolute weights for 100,000 lbs. pull are 200 lbs., 1,000 lbs., and 2,000 lbs. in the Werder, Greenwood, and Wicksteed machine respectively. In the Werder, however, the small weights have to be put on a scale-pan one at a time, and by hand, while in the other machines the load can be increased continuously by rolling out a poise-weight. The latter plan is clearly the most advantageous, not only in itself, but because of the ease with which it admits of the use of an accumulator and the addition of automatic diagramming apparatus of various kinds. In the Wicksteed machine the poise is always the same; the distance which it moves along the lever depends, therefore, upon the size of the test-piece.[1] In the Greenwood machine the poise is made up of a number of movable pieces, and the number of these used is made to vary with the size of the test-bar, so that the amount of motion of the weight is independent of the size of the piece, and is approximately the same for all test-pieces. This the Author considers to be a very considerable advantage, both from point of view of convenience and of accuracy.

As between the English machines, although in both types it is equally easy to start from zero load, the Greenwood machine requires a special balance-weight to be put on for this purpose, while with the Wicksteed machine the equilibrium of the main lever can be checked at any moment by running the ordinary weight over the main fulcrum.

(iii.) *Making of Observations.*—In cases where observations of extension, &c., have to be made at a series of loads increasing by equal increments, it is very convenient that these increments should be in round numbers of lbs. (1,000, 2,500, &c.) per square inch, rather than in round numbers of lbs. total. That is, it is more convenient to work with equal increments of stress than of load. With the Werder machine the former is so inconvenient as to be practically out of the question. With either of the English

[1] This is strictly true only up to 50 tons pull, above that load an extra ton weight is put on the end of the steelyard, and the movable weight brought back and again started from zero.

machines, however, it is perfectly easy. The Author always fixes first the weight of poise to be used, so as to give as large a motion on the steelyard as possible, and then calculates the position of that weight on the steelyard scale for the required series of stresses. It is hardly necessary to point out how much more convenient for all purposes such results are than if they were taken for equal increments of load, which had afterwards to be calculated into very inconvenient (although of course also equal) increments of stress, *e.g.*, 1,152, 2,304, 3,456, &c., lbs. per square inch.

(iv.) *Adaptability.*—In this respect the Werder machine has in certain points a marked advantage over the others. In it the ram and steelyard are both together at the same end of the machine, and the remainder of the apparatus is only frame, cross-head, and links, which can be lengthened, shortened, or otherwise altered with a minimum of trouble and expense. With the English machines, on the other hand, the space available for testing apparatus is strictly limited to that between the ram and the steelyard, and is in every way less free and alterable than in the Werder.

(v.) *Simplicity.*—The Wicksteed machine has only one straight lever, of 50 to 1, and may certainly claim to be simpler in design than either of the other types. The Werder machine has only one lever, but it is a knee-lever, having the enormous ratio of 500 to 1, and, in spite of its singleness, this necessitates a somewhat complex construction. The Greenwood is a double-lever machine, one of the two levers being a knee-lever. In actual constructive simplicity it comes between the two others. The advantage of the Wicksteed machine, from point of view of simplicity, is, however, probably greater than it appears to be at first sight, for in every horizontal machine the whole of the parts coming between the last knife-edges and the test-bar, which includes all clips and holding apparatus for one end of the bar, have to be slung from a knife-edged or frictionless form of links.[1] In the Werder machine especially, very large masses have to be slung in this way.

(vi.) *Accessibility.*—The straightforward simplicity of Mr. Wicksteed's machine is due to his adoption of the vertical position for the test-piece. With the horizontal types of machine one knee-lever at least is unavoidable, and certain parts of the machine, which in the vertical type simply form weights to be counterbalanced, must, as above pointed out, be slung by links, so as to

[1] A very good arrangement of hoop-links is used in the Werder machine for this purpose.

present a minimum of resistance to small horizontal displacements. In the absence of all this, the vertical machine has a certain advantage over the horizontal. For ordinary short test-pieces, both types of machines are probably equally convenient for experiment or demonstration. For pieces of any considerable length, however, the horizontal type has the advantage from both points of view. In fact, many of Bauschinger's experiments on long struts would have been practically out of the question in any vertical machine. In the Greenwood machine the whole length of every test-piece, the principal knife-edges, and the steelyard and its scale, are all as nearly as may be in one horizontal line, at a convenient height for the eye; with an overhead lever the scale and its vernier are somewhat inconveniently high up. In the Yorkshire College, Professor Barr has placed the foundation of the Wicksteed machine in the basement of the laboratory, and carried it up through the first floor. He has then made the working platform on the head of a hydraulic ram, which can be moved to any height between the two floors. This seems a very convenient arrangement, and allows the machine to test struts up to 10 feet in length; but the additional apparatus appears a somewhat dear price to pay for the sake of getting the vertical type of machine. The notion that a strut tested in a horizontal machine would naturally tend to buckle downwards, because of its own weight, seems a mistake. The Author has found just as many to buckle upwards or sideways as downwards. For the proper testing of a strut, stiffness and accuracy of end-bearings are practically the vital matters, and in this respect one type does not seem to have any advantage over the other. Satisfactory arrangements can be made with each.

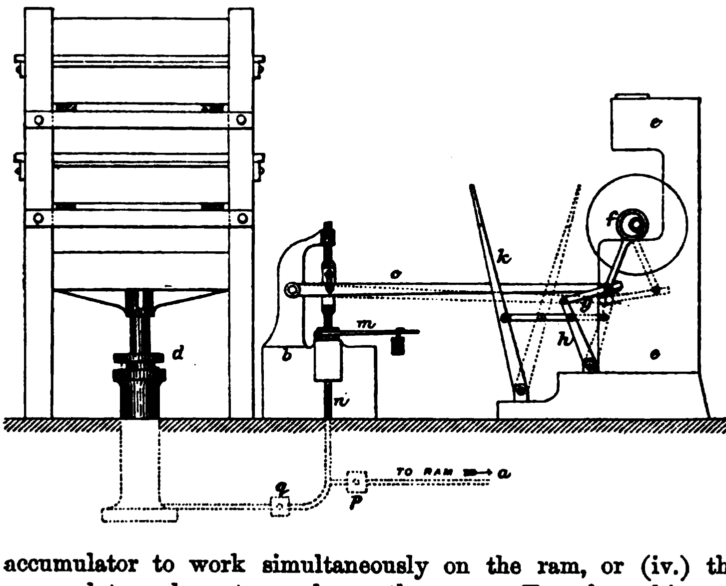
In concluding this comparison, the Author may be allowed to express his opinion that on the whole the balance of advantages lies with the Greenwood type of machine, in the form in which he is now using it. But he is aware how much of any such preference—in a case where all the things compared are good—may be due to use, and has endeavoured in his comparison to give each type credit for the particular advantages it undoubtedly possesses.

Method of Testing.

The method used by the Author in working his testing-machine is shown in Fig. 8, where *a* is the delivery pipe to the testing-machine, *b* an ordinary force pump with lever *c*, *d* an accumulator loaded to about $1\frac{1}{2}$ ton per square inch. The pump is worked by a

Davey motor *e*, on the shaft of which an eccentric *f* drives the free end of a double bar link *g*. The inner end of this link swings on a lever *h*, which can be thrown in or out by a hand lever *k*. According to the position of the link, the stroke of the block driving the pump lever varies from zero to the stroke of the eccentric. In this way the stroke of the pump can be modified, or its action entirely stopped by the hand lever, without stopping the engine. A relief valve *m* is fitted in the pump itself. *n* is the delivery pipe from the pump, with two regulating valves *p* and *q*, which allow the pump to pump either (i.) to the accumulator or (ii.) to the ram direct, or (iii.) pump and

Fig. 8.



accumulator to work simultaneously on the ram, or (iv.) the accumulator alone to work on the ram. For the taking of diagrams and other delicate work the accumulator alone is used, its speed being regulated by throttling through both the valves *p* and *q*. For ordinary work, where speed is an object, pump and accumulator are used simultaneously, the accumulator being pumped up the distance it has fallen during the replacement of the broken test-piece. The accumulator load is divided into four parts, of which any or all can be used simultaneously, or shelved, according to the required load. The Author does not think that an accumulator is by any means necessary for ordinary testing, that is, its

use or non-use will make no difference in the breaking-load, limit, or extension of a piece of iron, if only the test be carried on with proper care. Even for diagram purposes very good results can be obtained with an ordinary pump working with very short strokes—although great care is then required—and still better and with less trouble from a screw-pump like Mr. Wicksteed's. But probably the maximum of steadiness, as well as of convenience in working, will be found in some such system as that of Fig. 8, which the Author finally adopted about a year ago.

Measurement of Elastic Extensions, &c.

A most important part of the work of an engineering laboratory consists in the investigation of the behaviour of constructive materials under stresses such as those materials are actually subjected to in practical work. These stresses of course lie far below the limit of elasticity, and so correspond to strains or alterations of form not visible without special magnifying apparatus. Every laboratory must possess some means for measuring these small strains. The apparatus generally used may be divided into three classes, those namely which utilize—(i.) direct measurement by verniers or micrometric methods, (ii.) optical exaggeration of strain, (iii.) mechanical exaggeration of strain. Each type of apparatus can be modified to suit the different kinds of strain, so that it will be enough to speak chiefly of the measurement of *extensions*. The first essential in any apparatus of the kind under discussion is that it shall measure only changes of length in the test-piece itself and between certain definite points in it, and be totally unaffected by any changes of shape occurring in the frame or any other part of the machine, or by any possible motion of the test-piece as a whole. Only apparatus in which this condition is fulfilled will therefore be mentioned.

Magnitude of Strains Measured.—Professor Jenny's apparatus reads by micrometric methods to $\frac{1}{1000}$ millimetre, or say $\frac{1}{25,000}$ inch. Professor Unwin's micrometric apparatus can be arranged to read to $\frac{1}{20,000}$ inch or $\frac{1}{50,000}$ inch. Professor Bauschinger's mirror apparatus reads to $\frac{1}{500}$ millimetre directly, and by a somewhat uncertain estimation to one-tenth of this. The Author's lever apparatus can be trusted to $\frac{1}{10,000}$ inch. It is so constructed that it can be altered so as to read to $\frac{1}{20,000}$ inch, but he has not found so small readings to be necessary hitherto, the coarser readings being still fine enough to give from ten to twenty separate observations within the elastic extension of ordinary test-bars.

Direct Measurement of Extensions.—The form of direct measuring apparatus used by Professor Jenny of Vienna, and devised by Mr. G. Starke,[1] consists essentially of two micrometric microscopes adjustable separately both along and across the axis of the test-piece. The readings of this apparatus are entirely unaffected by strains in the testing machine, and are, moreover, easily calibrated at any time, but it is a somewhat elaborate and expensive piece of apparatus, and no part of it is usable for any experiments except those in direct tension and compression. Professor Unwin has shown the Author a micrometric arrangement devised by him, which appears to be as trustworthy as the one just described, and to have very great advantage on the score of simplicity. One microscope only is used, focussed over a point on one end of the specimen, and held in a rigid arm attached by a special form of clip to the other end. With a low-power glass readings can be got with certainty to $\frac{1}{20,000}$ inch, with a higher power to $\frac{1}{50,000}$ inch. For very delicate measurements of this kind it is of importance to have simultaneous readings on opposite sides of the test-bar, to which purpose Professor Unwin's apparatus lends itself very easily. For purposes not requiring such minute measurements, Professor Unwin uses, among other arrangements, the plan of measuring the extensions directly by verniers, held in hand between properly designed stops clamped to the test-piece, and adjusted by feel only. The "Extensometer" of Mr. E. A. Cowper,[2] M. Inst. C.E., is essentially a specially arranged vernier apparatus attached to two marked points on the piece.

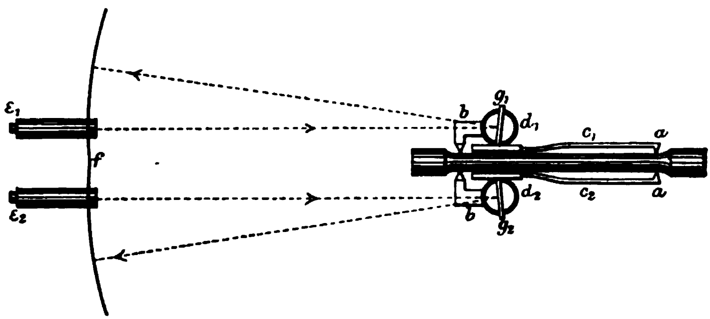
Optical Measurement of Strains.—Various forms of optical apparatus have been used for the purpose of measuring strains. One was exhibited by the Author at the Conversazione given by the then President, Mr. Bateman, to the members of the Institution of Civil Engineers in 1879, and was illustrated at the time in the technical newspapers. Experience in its use showed that its adjustments required extremely great care, and were by no means conveniently made, and that the connection of the mirror spindle to the frame of the machine was objectionable. He has therefore for a number of years given up its use in favour of the mechanical apparatus to be described below. Professor Bauschinger has from the first

[1] See Professor Jenny's "Festigkeits Versuche und die dabei verwendeten Maschinen und Apparate a. d. K. K. technischen Hochschule in Wien." Vienna, 1878 (Gerold's Sohn).

[2] Institution of Mechanical Engineers. Proceedings. 1878. p. 256.

used an optical apparatus of a much better form.[1] The principle of it is shown in Fig. 9. On the test-piece are fixed two clips *a* and *b*, at the desired distance apart. One of these, *a*, carries two light steel-plate springs c_1 and c_2, which pass along the whole length of the test-piece, and press outwards against vertical rollers of hard india-rubber, d_1 and d_2, carried by the other clip *b*. These rollers form the bottom part of two vertical spindles, on the upper ends of which are carried adjustable mirrors g_1 and g_2. As the distance between the clips alters with the extension of the piece, the motion of the springs causes proportionate rotation of the rollers, and therefore of the mirrors, through very small angles. At a convenient position along the axis of the machine are placed two telescopes, e_1 e_2, one reading in each mirror, and across and above them a long horizontal scale *f*. Each telescope

FIG. 9.

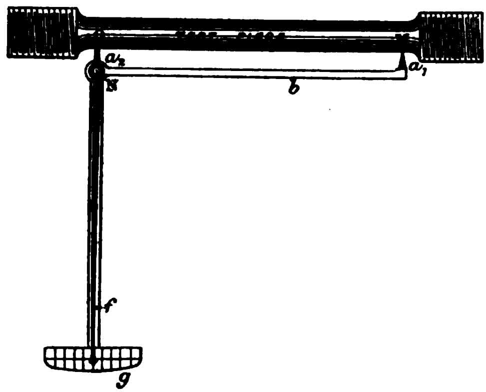


is set to read the reflection of the scale in its own mirror, and as the mirrors turn they reflect continually increasing readings on the scale. The true extension is taken to be the arithmetical mean of the two observed extensions, right and left, which eliminates errors due to initial or induced curvature of the test-piece. Bauschinger records his results in $\frac{1}{10,000}$ of a millimetre, and the uniformity of the differences he obtains is often very striking. It may be pointed out, however, that such results are generally used in the form of a curve, that an exaggeration of 500 : 1 is generally most ample for the scale of such curves, and that even with such an exaggeration even $\frac{5}{10,000}$ of a millimetre is only the thickness of a line. It may nevertheless be worth while to record the last place of decimals, if its estimation be reasonable, in order to give additional value to the next figure.

[1] See Bauschinger's "Mittheilungen," already referred to.

Mechanical Measurements of Strains.—In the measuring apparatus used by the Author the extensions are exaggerated by mechanical means. The apparatus is shown in detail in Figs. 1, Plate 1, and its principle in Fig. 10. The extensions are measured between points marked on the test-piece by a centre-punch made of larger angle than usual, but not in any way blunt in the point. In the holes so marked rest pins, a_1 and a_2, of which one (a_1) is connected with a rod *b* (of adjustable length), which at the end next a_2 carries a fork *c*. To the pin a_2 is rigidly attached a stirrup *d* embracing the fork, and jointed to it by the set screws *e e*. The stirrup also carries a long light pointer *f*, the end of which moves over a scale *g* at the end of an arm *h* attached to the fork *c*. The whole appliance is equivalent to

FIG. 10.



a connecting rod of length M N, and crank of length N O (Fig. 10), the latter being continued in a long arm in order to make its motions visible. The whole apparatus is slung on the test-piece, and is totally unaffected by its motions as a whole, and of course also by any change of form in the frame of the machine, &c. The axis of the scale is placed parallel to the axis of the test-piece. The extension of the test-piece is represented by the axial component only of the motion of the pointer, and can therefore be read off at once on the scale. The Author uses an exaggeration of 100 to 1, but he has tried the same apparatus with an exaggeration of 200 to 1, and finds it works satisfactorily. The exaggeration of the apparatus is made in the first instance as nearly right as possible, and the whole affair is then placed on vernier callipers and calibrated, the necessary corrections being made simply by

altering the position of the mark at the end of the index. The fact that the scale itself shares the whole motion of one end of the piece causes an error of 1 per cent. in the readings, which can be allowed for when that amount of accuracy in the value of the modulus of elasticity is required. The Author has made a number of sets of this apparatus, and has used it now for a number of years, and his experience enables him to say that so long as the points are in good condition, and such care is taken in setting it as it is reasonable to expect in a laboratory, it is free from back-lash, or at least has not back-lash exceeding $\frac{1}{10,000}$ of an inch, the smallest amount which it is attempted to read.[1]

The strain indicator of Mr. C. E. Stromeyer, Assoc. M. Inst. C.E., recently described to the Institution of Naval Architects,[2] has been often used by the Author. It is self-contained, and very handy to carry about and apply in all sorts of awkward places where his own more bulky apparatus could not be manipulated. But as at present made, it hardly appears suitable for laboratory use, where accuracy is of more importance than portability. Its accuracy depends essentially on the absolute roundness of an exceedingly fine wire (0·005 inch in diameter), and the results obtained with it seem to show that the wire is rather a very many-sided polygon than a cylinder, and that its diameter is by no means constant. Notwithstanding this, there is ample field for the use of this instrument in other places than laboratories.

The instruments used for measuring compressions, deflections, twists, &c., are in general modifications of one or other of the forms of apparatus described. The Author will only mention two special pieces of apparatus of this kind. One of them, which he has used himself, and which is the design of Mr. Stromeyer, is for measuring the change of diameter which accompanies tension or compression, so as to enable the value of the transverse modulus of elasticity of a material (the modulus generally calculated from experiments on torsion) to be found from tensional experiments alone. Mr. Stromeyer's apparatus is based upon the phenomena of light interference, and the strain (alteration of diameter of the test-piece) is measured by counting the number of interference

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[1] Professor Gollner uses a strain indicator in which Bauschinger's spring plate and roller (Fig. 9) are combined with a lever and scale such as those just described. The apparatus is double, so that simultaneous readings can be taken on two sides of the specimen. The scales read, by help of a vernier, to $\frac{1}{50}$ millimeter. The apparatus is fully described in the work of Professor Gollner, mentioned on p. 5.

[2] Transactions of the Institution of Naval Architects, vol. xxvii. p. 33.

lines passing across the field for a given change of load, and calculating the corresponding motion from the known wave-length of light from a certain source. It is natural that much difficulty should be found in the obtaining of accurate results from an apparatus measuring quantitatively such minute changes as this one does, and also in calibrating the instrument. But these difficulties seem now to be in the main overcome. The apparatus used by Professor Unwin for measuring the compression of stone blocks is admirably simple, although adjustable in all directions. The strain is multiplied by 3 mechanically, and then read off micrometrically.

Automatic Test-Recording Apparatus.

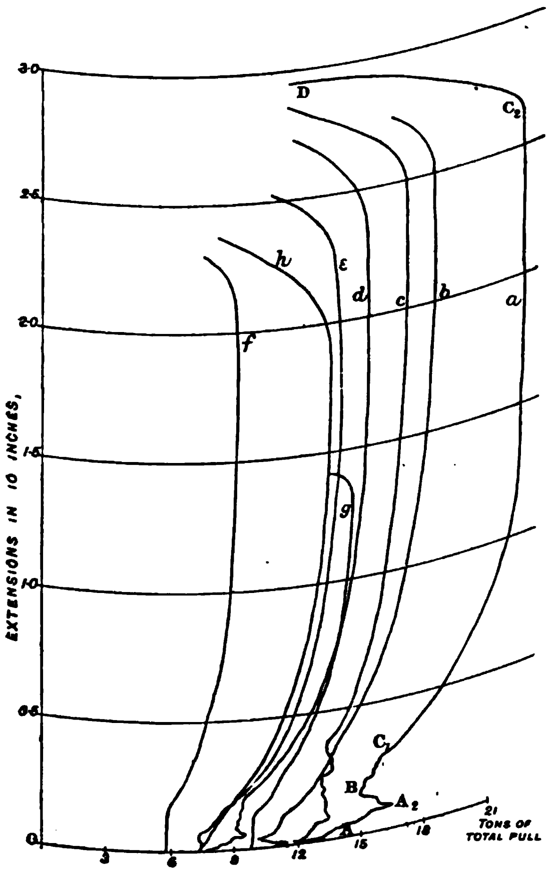
In 1876 Professor Thurston exhibited at Philadelphia his apparatus for drawing automatically the stress-strain diagram of a piece of material under test. This apparatus was adapted only for torsional tests, and had the serious defect of recording other strains than the simple twist of the test-piece; but drawbacks of this kind may well be overlooked in the first machine of a new kind. Great improvements in diagramming apparatus have been made within the last few years, and some autographic test-recorder should no doubt now form part of the apparatus of every engineering laboratory.

It is now sufficiently well known that the life of most ductile materials under test is represented by a diagram such as those of Fig. 11. $O\,A_1$ represents the very small elastic extensions, strictly proportional to the stress, and corresponding therefore to some constant value of the modulus of elasticity. $A_1\,A_2$ a stage (not always present) in which the strain, still very small, increases faster than the stress, and in which permanent set always occurs. A_2 is the point which the Author[1] has called the "break-down" point, a better name for which is, perhaps, however, *yield-point.* $A_2\,B$ is the remarkable fall or "release" of stress which often takes place after the yield-point. $C_1\,C_2$ represents the main part of the stretch of the bar, while it is in a condition of "uniform flow" or of semi-plasticity. Nearly all of this stretch—except the very small amount which would be represented by the ordinate of the line $O\,A_1$ if it were prolonged—is permanent set. C_2 shows the point of maximum load, usually called the breaking load. $C_2\,D$, lastly, shows decrease of stress as the bar draws down or flows locally, the load at D being the terminal load. The stage $A_1\,A_2$ is some-

[1] Institution of Mechanical Engineers. Proceedings. 1881. p. 211.

times absent or minute, $A_2 B C_1$ takes most various forms, $C_2 D$ also takes very various forms, or may be absent altogether. But a complete test-recorder ought to be able to show all the stages accurately where they exist. It has been said that the stages $C_2 D$

FIG. 11.



Automatically drawn stress-strain curves for wrought-iron and steel:—a = Swedish bar iron; b = Shelton bar iron; c = Swedish iron; d = Landore rivet steel; e and f = Landore plate; g = cast-steel; h = mild steel bar.

and $A_2 B$ are not of any practical importance. For works testing it is quite possible that both may be neglected without the loss of much valuable information; but it should not be overlooked that the former gives very much the same information about a material as is obtained by measuring its reduction of area. Without dis-

cussing this point, however, it may be said at once that it seems inadmissible to neglect both, or either, in scientific experiments, not only for the sake of accuracy, but because there is by no means yet a full knowledge of the practical bearing of either of these stages.

Diagram-drawing apparatus can be fitted to any testing-machine in which the load can be continuously altered.[1] The difficulty about the matter is that if the measurement of stress be taken from the position of the poise, or monkey-weight, as it is obviously natural to do, it is very difficult to get the stages $A_2 B$ and $C_2 D$ rightly, because for them the weight has to be rolled back again while the steelyard is still kept floating. The earliest apparatus of this type was that of Mr. Mohr,[2] as applied to the Mohr and Federhaff testing-machine already mentioned. The pencil was moved from the poise weight, the paper drum rotated proportionally to the extension of the specimen. The return at the yield-point could not be obtained, and the final return only by floating the weight back by hand. Some defects in detail natural in a first apparatus have probably been rectified since it was illustrated. The first diagramming apparatus of Mr. Abbott[3] (1877), and the later but more perfect apparatus of Mr. Pohlmeyer were only adopted to pendulum-weight machines, a type which has so many disadvantages as to be quite out of the question for such purposes as those now under discussion. In Professor Unwin's apparatus,[4] which also belongs to this class, and which is both simple and skilful in design, and convenient in arrangement, the final stage $C_2 D$ is also obtained by clever manipulation (backwards) of the poise (Fig. 12). The release at the yield-point can, however, at best be only imperfectly obtained in this way, and in this respect the apparatus is defective, although in others it is, perhaps, the most easily applied of all the forms of apparatus of equal pretensions to accuracy which have yet been proposed. Mr. Aspinall's apparatus,[5] and those of Professor Hele Shaw and Professor Hearson,[6] are essentially on the same principle,

[1] The Werder type of machine, unfortunately, does not, as at present made, lend itself to this purpose.

[2] Zeitschrift des Vereins deutscher Ingenieure, vol. xxvi. (1882), p. 545.

[3] "Testing machines," &c. By Arthur V. Abbott, p. 21. New York, 1884 (Van Nostrand).

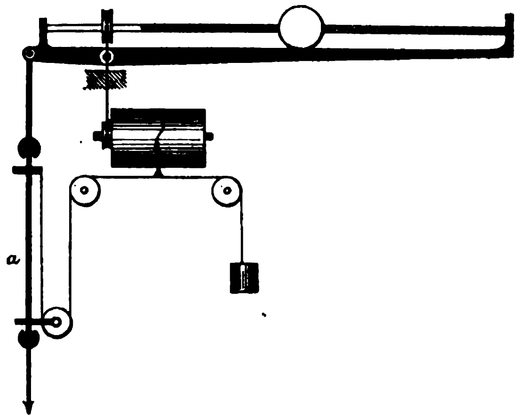
[4] Institution of Mechanical Engineers. Proceedings. 1886. p. 72; and Journal of the Society of Arts, 26th February, 1886.

[5] Institution of Mechanical Engineers. Proceedings. 1886. p. 89.

[6] Journal of the Society of Arts, 26th February, 1886.

but the latter has a mechanical arrangement by which the scale for extensions can be altered so as to draw the elastic part of the diagram on a larger scale (fifteen times full size) than the rest. In a recent Fairbanks' testing-machine [1] an arrangement has been made by which the movement of the poise is controlled by an electric relay, which moves it forwards whenever the steelyard rises against its upper stop, or backwards when it falls against the lower stop. The steelyard is thus kept automatically in balance. The stress-ordinate in the diagram is determined by the position of the poise. The arrangement is very complicated, requiring two sets of clockwork, two electric batteries, and a quantity of other apparatus. The published fac-similes of diagrams show that they are very imperfect at the yield-point, and that the apparatus is apparently insufficiently sensitive even to give the final drop properly.

Fig. 12.



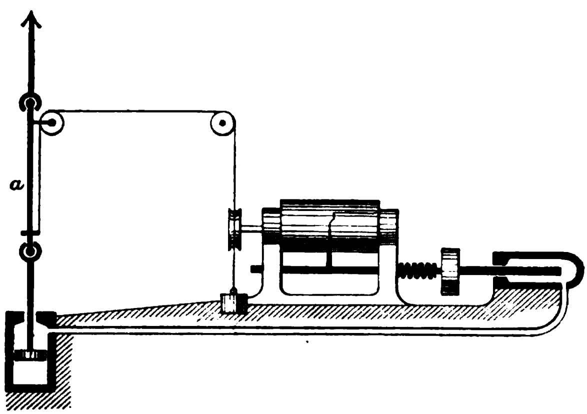
Mr. Wicksteed's apparatus[2] is believed by the Author to have been the first complete test-recording apparatus produced; it is sketched in Fig. 13. The measurement of the stress in the specimen is here not in any way, so far as the diagram is concerned, dependent upon the position of the poise, but is taken as being proportional to the compression of a spiral spring, acted upon by a small auxiliary ram in a cylinder in which the pressure is the same as that in the main hydraulic cylinder.

[1] Transactions of the American Institute of Mining Engineers, vol. xii. p. 607, 1884; and Mr. Abbott's work cited above.

[2] Institution of Mechanical Engineers. Proceedings. 1886. p. 27.

This auxiliary ram is kept in constant rotation so as to reduce its collar friction to an excessively small amount. The initial friction of the main ram is allowed for by initial compression in the spring, and its friction of motion is assumed to be proportional to the load. The apparatus is one which at first sight does not promise very regular results, but which in spite of this gives very good diagrams, and is obviously much more sensitive than any of its predecessors. Its sensitiveness is hardly sufficient, however, to show very clearly what happens at the yield-point, where the corners seem generally rounded away. The stress at the yield-point and the maximum load are noted by the position of the poise, and these two known loads fix the scale of the diagram, and serve to calibrate the whole instrument. The

FIG. 13.



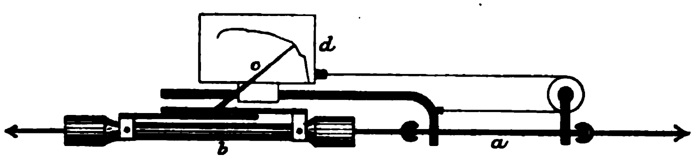
apparatus does not require any particular delicacy in handling, and is altogether constructed on the scale rather of a machine-tool than a piece of laboratory apparatus; this, for many purposes, is a great advantage. The constancy of rate of application of load is maintained by driving the screw-pump, which supplies the main ram, at a constant speed.

The apparatus devised by Mr. A. G. Ashcroft, Assoc. M. Inst. C.E., and the Author[1] differs in several ways from those previously described, and is entirely on the scale of an instrument rather than of a machine. It cannot be said to be suitable for general use for works testing; but for a laboratory, where it is in skilled hands, and not subject to rough usage, the Author believes it to be on the whole

[1] Institution of Mechanical Engineers. Proceedings. 1886. p. 63.

more sensitive, and to give more trustworthy diagrams, than any of the other forms yet devised. It has also the advantage that it is entirely independent of either the poise or the ram, or even any part of the framing of the testing-machine, and that its own parts are so extremely light that the diagram may be assumed to be free from any errors due to inertia. The principle of this apparatus is shown in Fig. 14, and its details in Figs. 2, Plate 1. The test-piece *a*, is placed in the machine in *series* (to borrow an electrical term), with a stronger bar *b*, called a "spring-piece," and the two, which are connected directly by a simple coupling, are pulled simultaneously, the one through the other. The spring-piece is of a material such that its limit of elasticity occurs only at a load greater than that which will break the test-piece. It must also be of material ascertained by previous experiment to be perfectly elastic, so that its extension is strictly proportional to the pull on it, and therefore to the pull on the test-bar. By a simple arrangement a very light pointer *c* is made to swing

FIG. 14.



about an axis through an angle proportionate to the extension of the spring-piece, and proportional therefore to the pull on the test-bar. The end of this pointer in its motion always touches a sheet of smoked glass *d*, to which is given a travel—in its own plane—proportional to the extension of the test-piece, and in this way the diagram is drawn. After the experiment the glass is varnished, to fix the black, the necessary particulars about the test are written on it with a scribing point, and the whole is used as a negative and multiplied by photography. By an arrangement of differential levers it is assured that the motion of the glass depends solely on the extension between the marked points on the test-bar, so that no amount of extension in the coupling, in the ends of the test-piece, or in any other part of the apparatus, can move the glass. The apparatus is also so arranged that the absolute elongation of the spring-piece does not cause any motion of the pointer relatively to the glass. The diagrams drawn by this apparatus (of some of which Fig. 11 shows fac-similes) have the drawback that their load-ordinates are arcs of circles instead of straight lines. The Author

has not yet succeeded in devising a plan for getting rid of this difficulty without unduly interfering with the sensitiveness of the apparatus. The rate of application of load is kept sufficiently constant and slow by using water from the accumulator, and throttling the valve between the valve and the ram.[1] There is no difficulty in floating the steelyard as far as A_2, and from C_1 to C_2 (Fig. 11). It drops at the end, and for most irons and steels also at A_2. But (as with Mr. Wicksteed's apparatus) these points are wanted only to scale the diagram accurately, the taking of the diagram would go on equally well if the steelyard were held down the whole time.

Elastic-Strain Diagrams.

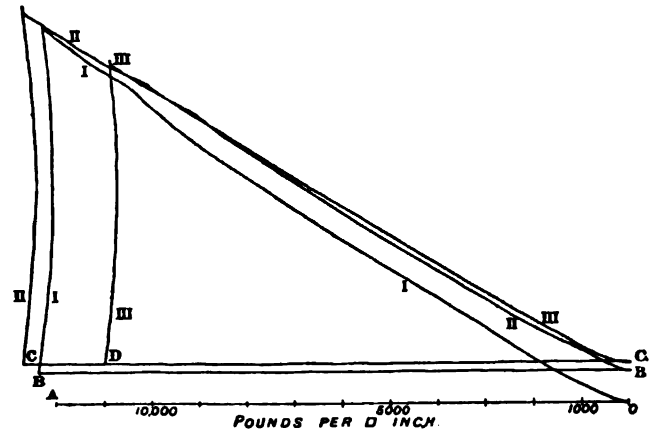
The difficulty in the way of obtaining a proper diagram of the *elastic* part of a stress curve lies in the fact that for ordinary pieces 10 inches long the extensions must be magnified one hundred or one hundred and fifty times—better still more—in order that the curve may be of use. Professor Unwin devised some years ago for this purpose what he calls a "semi-automatic" apparatus,[2] which, while it does not actually draw a diagram, determines a number of points upon one in a very convenient manner. A paper drum is made to revolve in such a way that the distance turned through is proportional to the motion of the poise, and therefore to the stress in the test-bar. A pencil is placed upon a slide parallel to the axis of the drum, and is so connected with an electro-magnet that it moves one step along the slide each time a current is made to pass. A microscope or other suitable instrument is connected to the test-piece and continuously observed during the stretch. At each $\frac{1}{1000}$-inch extension (or other smaller distance) the observer makes the necessary contact, and so causes instantaneous motion of the pencil. It is obvious that the diagram so drawn may be on a very large scale, and that (within the limits of the accuracy with which the observer can make the contact at the right moments) it will give a series of points (the angles of a stepped figure) upon a stress-strain curve. This is the first successful attempt, so far as the

[1] To get a good diagram it is best to use a large excess of pressure in the accumulator, and not too slow a speed (say five minutes for the whole diagram). With too small an excess of accumulator pressure, and too much throttling at the valve, the latter is apt to choke itself, and it is difficult to alter the amount of opening during the test without the curve showing some small "kink."

[2] Journal of the Society of Arts, February 26, 1886.

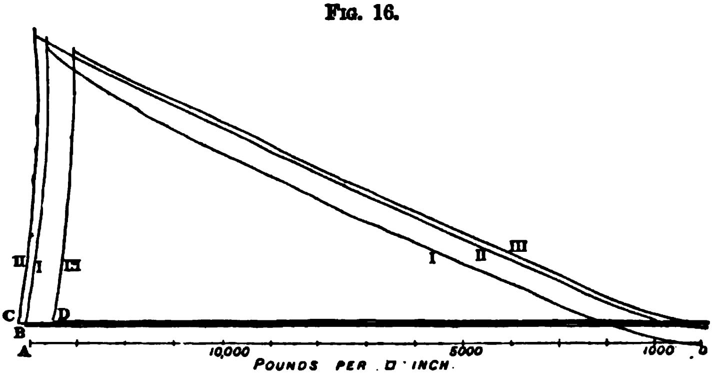
Author knows, to get the elastic part of such a curve drawn

FIG. 15.



Automatically drawn elastic curve diagram of a piece of cast-iron (Blaenavon), 0·75 inch in diameter and 10 inches long. Curve I was first drawn, the piece taking considerable set, obviously chiefly after about 10,000 lbs. per square inch had been applied, and coming back finally to a new zero line, showing set = A B = about $\frac{1}{710}$ inch. The load then at once re-applied gave curve II, which finally almost runs into I, but shows (on removal of load) a small set B C. The curve III was then at once drawn, and it almost coincides with II, and finally goes back (at D) to the same zero line, showing no further set. Original exaggeration of extension 130 : 1. The small continuations of the extensions at the end of each experiment show, apparently, "time effect."

FIG. 16.



Automatically drawn elastic curve diagrams of a piece of cast-iron (Carron), 0·75 inch in diameter and 10 inches long. The curves correspond to those of Fig. 15; there is, however, rather less set A B. The apparent additional set between the III and II experiments may be due to apparatus error, but two further curves from the same bar gave coincident curves, with no further set, real or apparent. The "time effect" is here very marked, especially in curve I. The loop at starting is no doubt due to manipulative difficulties.

automatically in a serviceable form. It appears to him that it is not only ingenious in itself, but capable of considerable develop-

ment, and that it may possibly turn out in the end, by the application of an automatic contact-maker, to be the basis of the most suitable method for drawing such curves. The Author himself recently devised a modification of the diagramming apparatus already described, which gives the desired curve about one hundred and fifty times full size on smoked glass. The spring-piece is not now used, but the swinging pointer is placed on the test-piece, and used to measure its extensions. The frame is also carried by the test-piece, and the glass moved by the poise directly. There is here no such objection to doing this as formerly, because within the limit of these experiments there is no going back of stress. It requires very careful manipulation to ensure that the glass starts at the instant at which the piece begins to stretch, and any inaccuracy in this matter spoils the starting-point in the diagram, although it leaves the rest of the curve unaffected. The figures show sufficiently to what extent this difficulty has been overcome. As with the Author's other diagrams the ordinates of these curves, which in this case represent extensions, are curved, and require rectification before the real nature of the curve can be seen. Although the apparatus is thus by no means in an ideal form, the diagrams which it gives are at least accurate and automatically drawn, and give record of matters, as in Figs. 15 and 16, which are of great interest, and which have hitherto been known only as the result of long and laborious detail measurements.

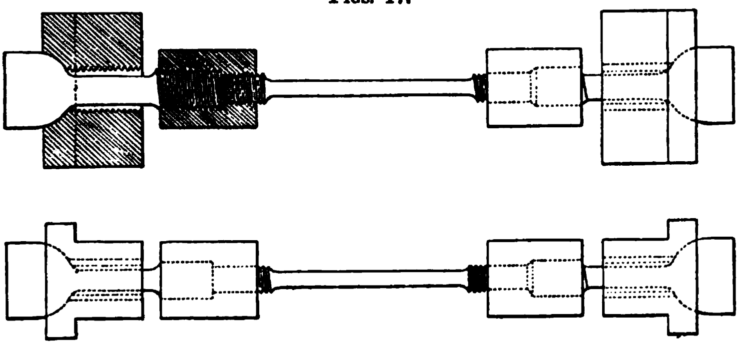
Methods of holding the Test-piece.

The method of holding, as well as of adjusting, the test-piece in the machine is a matter requiring special attention in the case of measurement of elastic strains. It is chiefly and essentially necessary that the line of pull should be coincident with the axis of the bar, and that under no circumstances should the pull cause any bending action in the bar. If proper precautions be taken in adjusting the test-bar in the first instance, there is no difficulty with any of the methods of holding ordinarily used, in obtaining a result sensibly correct as to limit and breaking-load with material of reasonable ductility. The Author found, for instance, after very careful experiments, made for the purpose of comparing stiffened pin-ends of the best construction with ordinary widened ends held in self-adjusting wedges,[1] that there was no difference

[1] Institution of Mechanical Engineers. Proceedings. 1881. pp. 206–7, and Tables I. to VII.

which could be said with any certainty to be due to the method of holding.[1] But with hard materials, such as cast-iron, the breaking load may be very easily and greatly influenced by the accuracy of centering, and the presence of even a very slight tendency to bending. The Author now finds that it is sufficient to use test-bars of ordinary round form, with enlarged and screwed (or collared) ends, if only they are pulled from spherical or ball-holders. He has devised the holder shown in Figs. 17 for this purpose. So far as he has yet tried, he finds that quite as large a proportion of cast-iron pieces pulled thus break in the middle, as when made with large eye-end, as is common, and pulled from pins. The test-bar should of course be cast on end. For the measurement of elastic strains, whether the material be hard or ductile, the proper holding and adjustment of the test-bar is much more important

Figs. 17.

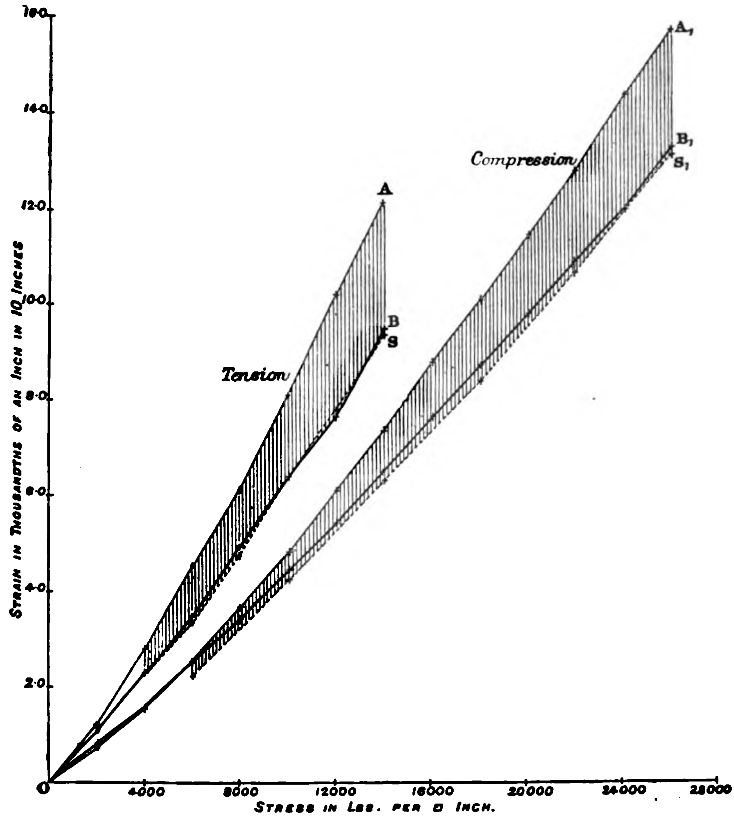


than for simple testing to fracture. To determine accurately the modulus of elasticity of a piece of plate, for example, it is practically necessary, under all ordinary circumstances, to measure the extensions on both sides and take the mean of the two sets of readings. This is doubly necessary in the case of plate, which is often not itself accurately straight, and straightens in pulling, thus making the apparent extensions on one side too great and on the other too small. In any case the *first* set of measurements should never be taken as giving data for calculation of modulus of elas-

[1] For this and other reasons, the Author ventures to think that the decision of the second German Testing Conference (Bauschinger's Mittheilungen, Heft xiv. p. 148, 1885) that self-gripping wedges are essentially faulty and should not be used, is a mistaken one. The ends of the test-piece should, however, be well widened, as is shown in No. 4, Fig. 4, in the Minutes of Proceedings Inst. C.E. vol. lxxvi. p. 107.

ticity. All material, as received, is more or less in a state of strain, and before its elastic extensions can be determined it must be brought to a "state of ease,"[1] by the repeated application, until no further permanent set appears, of a stress exceeding that

Fig. 18.



Cast-iron. O A and O A_1 are the first strain curves, giving sets which, set back from O A and O A_1, give curves O S and O S_1, the ordinates of the shaded areas representing amounts of set. O B and O B_1 are second strain curves (in tension and compression respectively), their ordinates closely coinciding with those of the curves O S and O S_1, showing that the material was reduced by the first straining to a state of ease.

up to which the modulus has to be measured. Fig. 18 illustrates this point. The line O A is the first measurement of the extension

[1] A most useful expression proposed by Professor Karl Pearson. See Nature, vol. xxxi. (1885), p. 457; also "History of Elasticity," Todhunter and Pearson. p. 886 (Camb. Univ. Press).

of a piece of cast-iron, the ordinates of the shaded area under it representing the set found during experiment. The line O B represents a second measurement of the same piece. It will be seen that the application of the load once was sufficient to bring the bar to a state of ease, and that the real elastic extensions have never varied, that is, that the line O B represents extensions which coincide sensibly with the elastic part of the extension O A.

As to the shape of the test-pieces themselves, it need only be said here that it is seldom advisable to test bars of uniform section throughout, however convenient it may be to do so on the score of cheapness, and further that the reduction of section from the ends to the parallel part should be by arcs of large radius, not by small quadrantal fillets. This is particularly the case with the harder qualities of steel and the commoner qualities of iron.[1] The most convenient length for all ordinary test-pieces, whether for scientific or other purposes, appears to be 10 inches in the parallel part—the length which Mr. Kirkaldy long ago adopted.

Size of Testing-machine.

The absolute size or power of testing-machine most suitable for laboratory purposes must be to a great extent a matter of opinion. In considering this point originally, the Author decided on adopting a pull of 100,000 lbs. as a suitable maximum. He was led to this conclusion by various considerations, among which the cost of the machine itself was certainly not an unimportant one. But after eight years' experience in the working of the machine, he believes that he would not get a larger machine, if he were now starting his laboratory afresh, and were limited to one machine, than at any rate 50 tons. The Werder machines in use are mostly machines of 100 tons, as are the Wicksteed machines used at Kensington, in the Yorkshire College and elsewhere. These larger machines have certainly the great advantage of being available for certain experiments otherwise impossible. But against this has to be set the fact that the enormous majority of scientific experiments do not require a pull of more than about 30 tons, and that it is a practical disadvantage to be handling, for such experiments, apparatus heavy enough for three or four times the maximum load used.[2] The Author believes that

[1] Minutes of Proceedings Inst. C.E. vol. lxxvi. pp. 107–119.

[2] The recent German conferences on testing, which have been attended by the most important experts from all parts of Germany and Austria, have decided that even for commercial purposes the standard breadth for test-strips of plate, all thicknesses, should be only 30 millimetres.

the most convenient arrangement for a laboratory would be to have two testing-machines arranged for tension and compression, one of 35 to 40 tons arranged to have the greatest attainable accuracy, to be in fact a large scientific instrument, and one of much simpler construction, perhaps of the Thomasset or Maillard type, and from 150 to 200 tons.[1] This could be used for such work as heavy riveted joints in tension, or brick or stone blocks in compression, when the same minute accuracy is not required as in diagram or elastic experiments. This larger machine at least should be horizontal, and should be arranged, like the Werder, so that the length of specimen tested might have no limit but the dimensions of the testing-house. As regards the length of test-piece for which the machine should be made, it can only be said that it should be as great as possible. In this respect a horizontal machine has the considerable advantage over a vertical, that every part of a test-bar, however long, is equally accessible and visible. The Author has arranged his machine so as to take struts of 8 feet 6 inches in length or tension-pieces of about 8 feet. But this might be exceeded with convenience, and is very greatly exceeded in the Werder machine.[2]

Testing-Machines for Compression, Bending, Torsion, &c.

It has been already mentioned that all the three types of testing-machine discussed are, or can be, arranged to make not only tensile, but also compressive, transverse, and torsional tests. For simplicity's sake the machines have been compared essentially with respect to tensile tests. It is matter for discussion to what extent it is advisable to multiply the functions of a single machine rather than to use separate machines for the different stresses. There is no doubt that it is convenient to have the principal testing-machine arranged for both tension and compression. For the latter stress it is above all necessary that any possibility of sideway motion of the dies between which the compression takes place shall be absolutely prevented. This the Author accomplishes by slides for the end of the piece pulled from the ram; and by top, bottom and side rollers for the end connected with the steelyard. This

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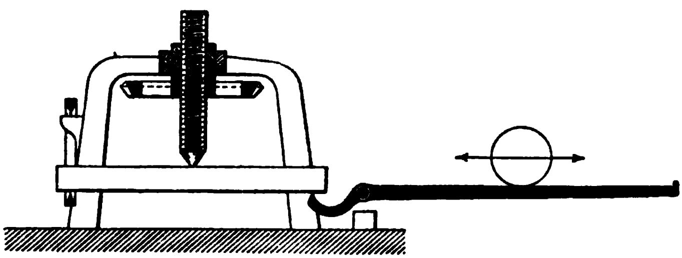
[1] Since the above was written the Author has found this arranged—although not with these particular loads—and already carried out in several of the German testing laboratories.

[2] The arrangement mentioned on p. 19, enables Professor Barr to get a length of 10 feet in his 100-ton Wicksteed machine. This machine has thus probably a larger capacity than any other vertical machine in existence.

part of the machine needs considerably more care in adjustment than the arrangement for tensile tests, and defective arrangement of it will give very inaccurate results.

Transverse Tests.—Transverse and torsional tests usually require loads so much less than the loads used in tension and compression, that it is probably better to carry them out upon separate machines. For laboratory purposes also, as one machine can only employ a small number of students at one time, it is necessary, or at least very convenient, to have several machines. The Author has an arrangement for transverse tests upon his large machine, but he has also designed a smaller machine specially for transverse tests up to central loads of 4 tons and spans of 5 feet. The machine is

Fig. 19.



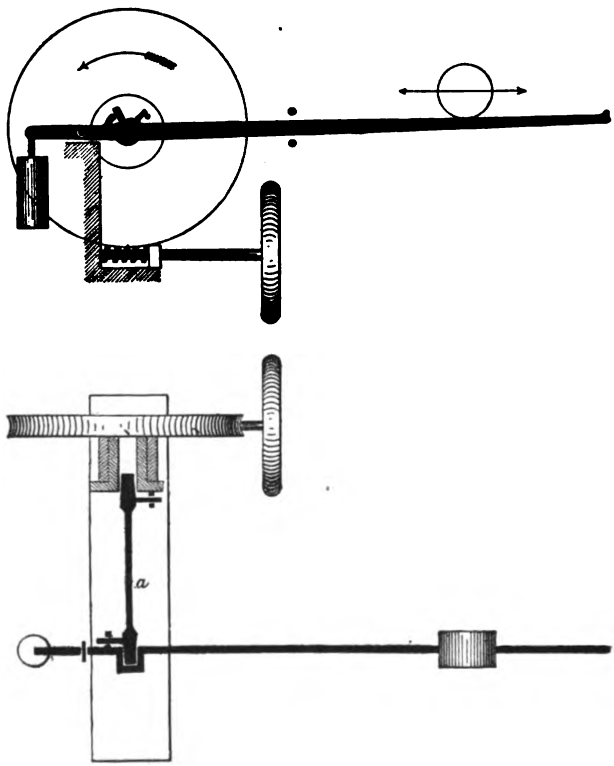
sketched in Fig. 19, and has been found to work very well. The load is applied by screw-gearing to the centre of the span, and measured by a steelyard and poise at one end.

Torsional Tests.—The arrangements for torsional tests often made in large machines are not only inconvenient, but sometimes essentially incorrect in principle, as well as capable only of taking very short specimens. Here, even more than for transverse tests, the use of a separate machine is very advisable. The machine used by the Author is sketched in Fig. 20. It works up to a twisting-moment of 4,000 inch-pounds. The twist is applied through a worm-wheel. The test-piece itself is turned at the ends and centred at one end in the mandril of the worm-wheel, and at the other in the boss of the steelyard. Before the stress is applied it lies quite freely in the bored holes which centre it; it is at all times free to move endwise, and is driven from an arm on the mandril through a friction-clutch.[1] A similar clutch at the other end of the test-piece transmits the pressure to the steelyard, and causes it to rise from its fulcrum and float. An arrangement is

[1] Minutes of Proceedings Inst. C.E. vol. lxxiv. Fig. 19, Plate 15.

made by which the actual lift of the steelyard end of the test-piece is kept so small as to be negligible. During a test the steelyard is kept floating by moving the monkey-weight out as the twisting moment is increased. This particular machine is not sufficiently powerful for many practical purposes. The Author believes, however, that it is accurate in working, although capable of great improvement from other points of view. A

Fig. 20.



machine capable of twisting asunder an inch bar of steel (say 14,000 to 16,000 inch-pounds) would be sufficient for most laboratory purposes. For measurements of elastic twist it could of course test much larger bars. The well-known pendulum-torsion machine of Professor Thurston (the first machine used with autographic diagrams, as already mentioned) is hardly suitable for laboratory requirements, as it will only take so short a test-piece

that its indications of elastic twist are valueless, and even its indications of final twist must be to some extent affected.

Shearing Tests.—For tests in "single shear," the Author has used an apparatus described in connection with his riveted-joint experiments for the Institution of Mechanical Engineers.[1] Experiments in "double shear" are, however, much more easily made, and are probably more trustworthy in their results. For this purpose it seems only necessary to groove the test-bar with narrow, shallow, rounded grooves, and hold it in the unturned part well up to the grooves, so that there may be no bending.[2] The same method applies even to shearing tests of cast-iron, but with such brittle material the holding up of the test-piece must be carefully looked to.

Cement-Testing.—Among other testing-apparatus a cement-tester is certainly an important adjunct in a laboratory. Professor Bauschinger made most elaborate and valuable experiments on cements and concretes in a 100-ton Werder machine, using, however, very large specimens, the briquettes for tension being often 11 square inches in section. The Author found his machine hardly suitable for dealing with cement briquettes of 1-square inch section without much trouble, for reasons that will be readily understood, and uses now a Kühlmann machine, for ¾-inch briquettes, which he has found quite satisfactory as far as he has tested it.

Wire-Tests.—Tests of very long wires may under some circumstances be useful. These, however, can hardly be said to require a testing-machine. Professor Barr has made special provision for them in recesses extending from basement to roof of the Engineering Laboratory at the Yorkshire College, Leeds, and this will no doubt be convenient. He has devised an autographic recording apparatus for wire-tests (somewhat similar to that used in Japan by Professor Ewing),[3] with which interesting curves have been drawn. It must never be forgotten, however, that results obtained from tests of wire, especially in regard to its behaviour at low loads, must not be taken as applying to the comparatively homogeneous and unstrained forms in which most constructive materials are used.

Secular Experiments.—Apparatus for secular tests of other material than wire, and especially of cast-iron in the form of

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[1] Institution of Mechanical Engineers. Proceedings. 1881. p. 214, and Plate 30, Figs. 2 and 3.

[2] *Ibid.* 1885, p. 237, and Plate 29, Fig. 10.

[3] Proceedings of the Royal Society of London, vol. xxx. (1880), p. 510.

beams, may well find employment in a laboratory, but would be essentially simple in its nature, and need only be mentioned.

Repeated Loads.—Apparatus for making tests of the effect of often repeated loads, such as those started by Wöhler, and greatly extended and still carried on under Mr. Martens in Berlin,[1] may also well find a place in a laboratory. But the expense of making and working the special machines necessary for this purpose has hitherto prevented them from finding place in any other laboratories.

Bending Tests.—A special plate-bending machine[2] is a useful addition to a laboratory, but its results are rather of general than of scientific interest. For works where such tests are regularly carried on, it is matter for surprise that such machines are not in general use.

Falling-weight Tests.—Falling-weight tests carried out in a laboratory might give results of much value, for they are too often made and recorded in works in exceedingly inaccurate fashion. The practical difficulty in the way of these tests is no doubt the noise and vibration which accompany them, which are apt to prove inconducive to scientific work on the part of all but the particular experimenter concerned.

It must be remembered that experiments in a laboratory are carried out by students for the two-fold purpose of obtaining certain results and of studying certain methods. And sometimes it is even more important to learn how to make an experiment than to obtain numerical results from it. From this point of view it is most valuable for students to be shown how to make experiments with a minimum of special apparatus, how to render such experiments trustworthy and accurate within certain limits, and how to estimate the value of these limits. By the very nature of things apparatus to be used in this way cannot be described beforehand, it must be put together by the experimenter from such materials as he has.

Experiments on the Working and Economy of the Steam-Engine.

Experimental Engine.

It has been necessary to some extent to distinguish between the requirements of a testing-machine for a laboratory and for works; but the distinction between an experimental engine and one for

[1] Appendix III, p. 73.

[2] See, for instance, Lebasteur's "Les Métaux."

ordinary use is far greater, and has to be carefully kept in mind. For the former the following may be said to be the essential requirements: The engine should be capable, when working at its best, of obtaining a very fair degree of economy, say, of working with 19 to 21 lbs. of steam per indicated HP. per hour. It should be capable of being worked under all the principal conditions possible in practice, both economical and wasteful. It should be fitted with appliances for measuring with the utmost possible exactness the data necessary for a proper comparison of its working under these different conditions. It should be large enough to give results which may be taken to represent fairly the results which would be obtained under similar conditions in practice. The main point is, therefore, not that the engine should attain as high an economy as possible, but that it should be capable of being worked in as many ways as possible, and the results measured in each way. The engine, in fact, may well possess a complexity which would be ridiculous in practice, for it must do duty at different times for a dozen different engines. The following may be noted as the principal conditions under as many as possible of which the engine should be capable of working:—

(i.) Condensing or non-condensing.
(ii.) Simple or compound.
(iii.) Compound with cranks at various angles.
(iv.) With the greatest possible variation of steam-pressure.
(v.) With the greatest possible variation of cut-off and other points in the steam distribution.
(vi.) With the greatest possible variation of brake power.
(vii.) With considerable variation in speed.
(viii.) With or without throttling.
(ix.) With or without jackets, and with varying conditions as to their use.
(x.) With variation of clearance-spaces.
(xi.) With variation of receiver-volume.
(xii.) With or without arrangements for intermediate heating.
(xiii.) With variation in the reciprocating masses.

The points numbered (i.), (ii.), (iv.) and (viii.) need no special remark.

(iii.) *Crank-Angles.*—The alteration of angles between the two cranks of an engine working compound practically involves the use of two cylinders (horizontal or vertical), placed side by side, with separate shafts connected by some form of coupling which

can be adjusted to a sufficient number of different relative positions of the cranks. This is a matter of considerable importance.

(v.) *Steam-distribution.*—An automatic cut-off is not a requirement of an experimental engine, as during experiments it must be working against a constant resistance, and therefore should have a constant cut-off. But a cut-off variable by hand should be applied to both cylinders. In the cylinder intended to work by itself when the engine is non-compounded, it should be possible to cut off at any point whatever of the stroke, and in the high-pressure cylinder working compound practically the same requirement exists. In the experimental engine of the École des Mines of Liége (which is a single-cylinder engine only)[1] arrangements are made for varying the lead as well as the cut-off, and also for varying the speeds of opening and closing the valves. For this purpose separate steam- and exhaust-valves are used, of the double-beat type. With slide-valves, of course, such alterations are impracticable.

(vi.) *Brake.*—The Author has found that for very small powers a special brake is required, differing from the ordinary Appold-Prony brake used for normal and high powers.

(vii.) *Speed.*—This involves the use of a governor corresponding nominally to the highest intended speed of the engine, and arranged so that it can be loaded, or otherwise adjusted, so as to make it work at lower speeds. It is preferable, of course, to work without a governor at all, and this ought to be possible where the resistance is practically constant. But the Author has found in his own case that if the engine is run without the governor it hunts rhythmically, that is, its speed goes through regular cyclical increases and decreases. These irregularities are much more injurious to an engine-trial than the small irregularities of pressure due to slight throttling. He therefore leaves the governor always in gear, arranging the throttle-valve lever so that the governor has just sufficient controlling power for the very small changes which occur.

(ix.) *Jackets.*—Each cylinder requires its own jacket, and the ends should also be jacketed. It should be arranged that either one or both can be used at one time, and that the jackets may either be filled with steam from a branch of the main steam-pipe, or by the engine-steam itself circulating through them on its way to the steam-chest. These changes are no doubt important, and they are very easily arranged for.

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[1] "Engineering," vol. xxx. pp. 397 and 516.

(x.) *Clearance-Volume.*—One proper way of arranging for variation of clearance-space would be to make the cylinder covers dish-shaped on the inside, and to place in the hollow of each cover a disk of such thickness as would bring the clearance-volume to the desired amount. The method used by Professor Unwin is virtually this in principle, but is perhaps a little more convenient in detail. Alterations of the clearance-volume by connecting the ends of the cylinders with any kind of small receiver outside themselves would so complicate the result, by introducing new conditions as to condensation losses, that it would probably be of little use.

(xi.) *Receiver-Volume.*—The receiver-volume has been made variable by Professor R. H. Smith, by arranging a movable plunger in what may be called a large pipe standing on the top of the ordinary receiver. Professor Unwin, for the same purpose, has adopted the plan of having a certain number of different sized vessels, which can be attached to a branch on the receiver proper. The difficulty of getting quantitative results of value from experiments on this matter will probably be found to lie in the variable losses from radiation due to the different conditions which thus come in with each change of volume. The most satisfactory arrangement will probably be found to be not to make the normal size of the receiver a minimum and enlarge it by additions, but to make its normal size a maximum and reduce it by internal boxes of various capacity. In this way the outside cooling surface would under all circumstances remain unchanged.

(xii.) *Intermediate Heating.*—The simplest arrangement for this purpose is, of course, a steam-jacket on the receiver, which can be used or shut off at pleasure. If internal boxes (as mentioned above) be used, they could be made part of the jacket, and would add very much to its available surface. It seems doubtful whether any arrangement for heating by fire or hot gases could be usefully tested on the small scale of an experimental engine.

(xiii.) *Reciprocating Masses.*—There seems no essential difficulty in arranging for the rigid attachment of varying weights to the cross-head, and interesting experiments might be made in this fashion with an engine capable of working with considerable variations of speed.

Measurements of Engine Efficiency and Economy.

The following are the principal measurements to be made during an engine-test:—

(i.) Steam pressure in boiler and in valve-chest.
(ii.) Barometric pressure in engine-room.
(iii.) Vacuum.
(iv.) Temperature of feed-water.
(v.) Temperature of injection-water.
(vi.) Temperature of discharge-water.
(vii.) Quantity of feed-water.
(viii.) Quantity of water from jackets.
(ix.) Quantity of discharge (or injection) water.
(x.) Revolutions of engine.
(xi.) Indicated HP.
(xii.) Brake HP.
(xiii.) Quantity of moisture in steam.
(xiv.) Quantity of lubricant.
(xv.) Indicated HP. of air- and feed-pumps.

Nos. (i.), (ii.), (iii.) and (iv.) of these require no remark except that the gauge used for No. (i.) must itself be verified and compared with the indicator-springs used for the high-pressure cylinder, which themselves also require verifying. No. (xv.) may be considered to be included in the remarks made below on (xi.).

(v.) *Injection Temperature.*—If the injection-water is taken from a tank or pond into which the discharge is returned, its temperature must be measured along with (vi.), otherwise it need not be measured quite so often. In any case a very delicate thermometer (with known corrections) must be used for it, with its bulb placed full in the current of water.

(vi.) *Discharge Temperature.*—The same remarks as to thermometers apply here. The best place in which to place the discharge thermometer must be found out by trial. No doubt that position will be best which gives the highest steady reading. In a four hours' trial the readings may be taken every five minutes; in a shorter trial twice as often.

(vii.) *Feed Measurements.*—The feed-water may be conveniently measured from any sufficiently large rectangular or circular tank previously calibrated. The Author uses a slate tank with a scale (determined by direct weighing-in of water) and pointer attached to a float. The feed-pump overflow should deliver back into the tank. The whole of the feed-pipes between pump and boiler

should be visible. They should be emptied (or alternatively kept equally full) immediately before and after the trial, and the necessary allowance made. The feed-pump of the engine should not have nearly so large a margin of size as is ordinarily allowed; it should only be just as large as is necessary for the conditions under which the engine uses a maximum of steam. It would be an excellent arrangement to have a feed-pump of variable stroke which could be arranged always to deliver as nearly as possible the quantity of water required. It is probably not advisable to use an injector instead of a pump in an engine-test, except under special circumstances, namely, where the engine trial is not also a boiler trial, and where the use of a surface-condenser allows the condensed steam from the engine to be separately measured. With a jet-condenser in which the injection-water is measured separately before it goes into the condenser, so that the quantity of water and condensed steam from the cylinders may be known as the difference between the measured injection and discharge, as well as calculated, it is possible that an injector may also be used.

(viii.) *Measurement of Water from Jackets.*—Each jacket should be provided with a trap, and the traps blown off before and after the experiment. By trial it will be found possible so to set the traps that they will dribble continuously during the experiment without any sensible accumulation of water. The Author has used Royle's spring traps for some years; they work steadily and give no trouble. There should be a separate trap for draining the main steam-pipe to the engine. The natural condensation in the jackets due to loss of heat by radiation may often be considerably greater than the condensation due to transmission of heat inwards to the cylinder. The former quantity should be separately determined while the engine is standing. To imitate exactly in this determination all the conditions of the engine trial except transmission of heat through the cylinder walls, steam can be led through the jackets to drive another engine, and in this way a forced circulation of steam can be caused. All the pipes, small and large, should be covered, and the thicker the covering the better.

(ix.) *Measurement of Discharge Water.*—This is carried out by measuring the head over a weir or orifice of some kind. The Author has always used a rectangular notch, of which the coefficient of discharge at different heads has been repeatedly determined by direct measurements. Special arrangements are made for gauging the zero points (water level with notch) easily before and after each experiment, and observations of head are made (by help of a

telescope reading on a scale) twice every five minutes. Probably a V notch, which ought to have a constant coefficient, would be more convenient than a rectangular one. The circular orifice used by Mr. Mair,[1] with a comparatively large head over it, has the great advantage that small errors in reading the head are of comparatively much less importance than with the notch. It is perhaps, however, less convenient for cases where the quantity of discharge in different experiments varies enormously, and where, therefore, different orifices, or a different number of similar orifices, would probably have to be used. But the advantage just mentioned is an important one. In the case of a jet-condenser the discharge includes the condensed steam and water from the cylinder, the amount of which can be found by calculation only, checked by direct measurement of the feed into the boiler. The check is not complete if the boiler primes at all (see under (xiii.) below), and in any case it may be convenient to have a second measurement of the steam through the cylinder. This is, of course, best obtained by the use of a surface- instead of a jet-condenser, and direct measurement of the air-pump discharge. With a jet-condenser the same result can only be obtained by the somewhat less satisfactory method of measuring the injection water on its way to the condenser. This the Author is at present arranging to do by a system of double tanks. He finds, however, that with steam dry initially, and the whole engine properly trapped, the quantity of steam calculated from the discharge, together with the weighed quantities from the traps and steam-separator, sensibly agree with the total measured quantity of feed-water which has been pumped from the feed-tank.

(x.) *Revolutions.*—The total revolutions should be registered by a counter, the uniformity of speed being checked from time to time by a speed-indicator or by counting. But an experimental engine working against a constant resistance should vary very little in its speed.

(xi.) *Indicated HP.*—It is hardly necessary to say that a separate indicator must be used for each end of each cylinder. It is advisable to interchange the front and back springs half-way through a trial. Both indicators and springs require testing from time to time, an operation much more easily prescribed than carried out. The Author has already placed before the members of this Institution some of his own experiments on this matter.[2]

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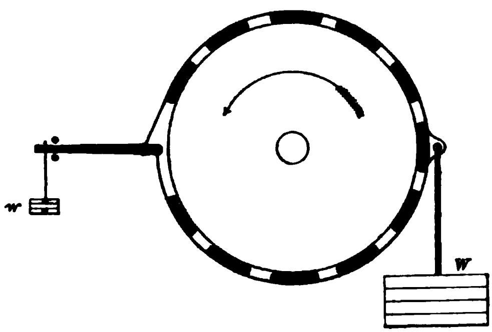
[1] Minutes of Proceedings Inst. C.E. vol. lxxxiv. p. 424.

[2] *Ibid.* vol. lxxxiii. p. 61.

Elbows in indicator pipes should be absolutely avoided, even bends of any kind are objectionable; in fact the only safe rule is that there should not be any indicator pipes at all,—the indicators should be placed direct on the cylinder bosses, the hole through which should not be less than ½ inch in diameter. If the use of connecting pipes is unavoidable they should be as short as possible, straight, large in diameter, and well covered with a non-conductor. Some type of drum gear is perhaps the best for reducing the stroke of the piston to that of the indicator, and the throwing out arrangement should be such that the indicator cords or wires are left quite alone,—not pulled backwards and forwards,—except at the instant when cards are being taken.

(xii.) *Brake HP.*—If the Appold pendulum-lever in any form is used for automatic adjustment of the brake, it should be so

FIG. 21.

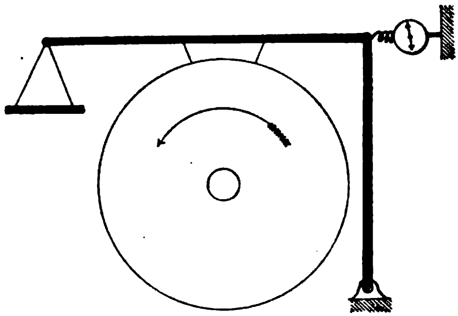


arranged that its own pressure can be measured and allowed for. The plan used by the Author, to whom it was suggested by Mr. R. H. Willis, Assoc. M. Inst. C.E., is sketched in Fig. 21. The small weight *w* is adjusted from time to time so as to keep the brake always floating freely, the changes of weight are noted, and the necessary allowance made in calculation of the brake HP. The Author believes that the side pressure of the upper end of the pendulum-lever, as it is arranged in the Royal Agricultural Society brakes,[1] if not measured and allowed for, causes a very considerable error in the calculated power. It is convenient that the brake should be large enough to run dry at all ordinary powers, as it is much more easily kept under control under these conditions. For all except the very smallest powers the Author uses the ordinary brake shown in the sketch, and finds that it works

[1] Institution of Mechanical Engineers. Proceedings. 1876. p. 217.

quite satisfactory. It is necessary that the ring of blocks with its fittings, including the pendulum-lever, should be in balance, or else the proper allowance made for the excess weight on the lever side. For working under very small brake-powers the Author uses a brake having only a single rubbing block kept in contact with the top of the fly-wheel by a weighted lever. The horizontal frictional pull is then measured by a horizontal spring-balance attached to the lever. The arrangement is sketched in Fig. 22.

FIG. 22.



It requires considerable care to keep the friction sufficiently constant to prevent inconvenient vibration of the spring pointer, but under certain circumstances this form of brake is a useful one.[1]

(xiii.) *Moisture in Steam.*—The presence of water in the steam when it reaches the engine is so exceedingly troublesome, in the final stages of such calculations as are to be made with an experimental engine, that every possible means must be used to prevent it. The most effectual means is no doubt the employment of a boiler which is proportionally far too large for the engine, and which has a large water surface, and can make steam quietly and easily for even the maximum power of the engine. Mainly for this purpose the Author put down in 1885 a boiler with double the heating surface of the former one, although the latter was large enough for the work. The result has been most satisfactory, the entire agreement of calculated and measured quantities showing that the steam is really dry. An ordinary diaphragm separator is used, placed close to the boiler, which is no doubt an additional safeguard, but it now gives very little water. The ordinary

[1] It will be noticed that it is really also a friction-measuring apparatus, as the coefficient of friction between block and wheel, of whatever materials, is directly determinable by it.

method of measurement of priming-water, by blowing steam into a vessel of water, is extremely unsatisfactory, and seems to fail to give trustworthy results even in skilled hands. A continuous calorimeter gives the best promise of success in this direction; such a calorimeter might perhaps be arranged so as to be trustworthy if it dealt with sufficiently large quantities of condensed steam, and sufficiently great range of temperature of the water.[1] Of the various chemical methods which have been proposed, the only one known to the Author which seems thoroughly promising is that of Mr. Ernst A. Brauer,[2] of Berlin, used on the exhaustive trials of six portable engines in Berlin, in October 1884. Shortly described, Brauer's method is as follows:—Before an experiment, a certain weight of solution of common salt is introduced into the boiler. At the beginning and at the end of the experiment, the water-level being the same, the amount of salt in the water in the boiler is determined, the feed-water used meanwhile having been ascertained to be free from salt, or to contain some known quantity of it. If the two amounts correspond, it is assumed that there has been no priming. If, on the other hand, the saltness has diminished, the corresponding amount of priming is easily calculated. The chemical determinations necessary are very simple, and capable of being easily carried out with extreme accuracy; and in every respect the probability of errors seems to be much less than in any method which involves a sampling of the steam (in itself not an easy matter), which inevitably includes any water of condensation from the steam-pipe as priming-water, and which finally depends for its accuracy on the determination of a small difference in a comparatively large weight, and the measurement of a comparatively small difference of temperature. In the Berlin trials, the results given by Brauer's method were most satisfactorily consistent, including even the results of intermediate determinations

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[1] There was a long discussion on this subject at the American Society of Mechanical Engineers not long since (vol. vi. p. 314), much of which may be read with interest. But the expressed views of many members as to what constituted accuracy in measurement leaves doubt as to the value of statements made as to the working of different pieces of apparatus. One gentleman shows in detail how easily errors of 50, 100, 200 per cent. and more in the estimated quantity of primary water may occur, but by some odd misapprehension he measures the errors as percentages of the total quantity of steam, instead of as percentages of the priming itself, and so makes them appear insignificant.

[2] Wochenschrift des V.D.I. 1883, p. 518. "Bericht über die . . . . Prüfung von Locomobilen." F. Schotte, 1884. Leipzig (Felix), republished from the Civil-Ingenieur, 1884, Nos. 4 and 5.

made during the progress of the trial while the water-level could not be accurately ascertained.[1] The Author hopes soon to have an opportunity of testing Brauer's method. It need hardly be added here that measurements of the moisture in steam, either initially or finally, based upon indicator-card pressures, can only be regarded as more or less useful approximations.

(xiv.) *Lubricant.*—It is not of so much importance to measure the lubricant used for the cylinders, as to keep it constant; any irregularity in supplying it makes a notable difference in the running of a small engine. It is probably best supplied by a screw oil-pump, by which the quantity can be measured, as well as delivered with the utmost regularity at any desired rate.

Types of Experimental Engine.

The Author does not know that there is any experimental engine in existence which fulfils all the conditions which he has specified. The only engines which he knows of as coming near it are (mentioned in order of their being put to work) those at the Munich Polytechnikum, at University College, London; the Mason Science College, Birmingham; the École des Mines, at Liége; the City and Guilds Central Institute, Kensington, and the Yorkshire College, Leeds; three of which are in the hands of members of this Institution. Of these, the largest is that of Professor Unwin, at Kensington, which has two (horizontal) cylinders, of $8\frac{3}{4}$-inches and $15\frac{3}{4}$-inches diameter respectively, and 22 inches length of stroke. This engine is now fitted with all the necessary measuring appliances to enable it to work with nearly all the variations of conditions specified above (p. 46), except (vii.), (xii.) and (xiii.), and some of the conditions of (v.) and (ix.). This engine was made by Messrs. Marshall of Gainsborough. At Munich Professor Schröter has two independent engines, the cylinder of each being 350 millimetres in diameter, and 640 millimetres length of stroke. One is a non-condensing engine with Rider valve, the other a steam-jacketed condensing engine with Sulzer valve-gear. The engine at Leeds just finished for Professor Barr, by Messrs. John Fowler and Co., will also be a very complete one. It has cylinders of 6-inches and 12-inches diameter and 12 inches length of stroke, placed horizontally side by side, but capable of

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[1] The Glauber-Salt method used at the Düsseldorf trials in 1880 ("Untersuchungen an Dampfmaschinen und Dampfkesseln in Düsseldorf." H. von Reiche, Aachen, 1881, J. A. Mayer), does not seem to the Author to have been by any means so satisfactory as Brauer's.

independent working. Professor R. H. Smith's engine at Birmingham[1] was built to his designs by Messrs. W. and J. Player, of Birmingham. It is a vertical inverted engine, with cylinders 6 and 12 inches in diameter and 10 inches length of stroke. It has been at work since 1883. Both these engines are capable of working under the principal variations mentioned. The Liége engine (in the laboratory of Professor Dwelshauvers-Déry) is a single-cylinder jacketed engine (cylinder 300 millimetres in diameter, and 600 millimetres length of stroke), made by Mr. Ch. Beer, of Jemeppe. Its special feature is that, by an ingenious arrangement of valves, all the points in the steam-distribution can be altered and adjusted at will. It is fitted with proper apparatus for calorimetric tests. The Author's engine is a tandem-compound, with cylinders 6 and 10 inches in diameter by 12 inches length of stroke, made by Messrs. Bryan Donkin and Co. some years ago for their own experiments, and coming into the possession of University College, mainly through the kindness of the makers, in 1882. Owing to its construction, the two cylinders work on the same crank, so that variation of crank-angle (condition iii.) is not possible, and variation of receiver-volume (xi.) is not useful. It can work, however, under most of the other specified conditions except (vii.), (x.), (xii.) and (xiii.). More than ninety complete trials have been already carried out with it, in which all the other variations have been more or less represented. The Author has devised the observation and result forms of which the headings are given in the Appendix,[2] and uses them in each trial, except for special experiments on mechanical efficiency, air- and feed-pump working, and so on.

It is no doubt a convenience that the principal experimental engine in a laboratory should not be used to drive machinery, but should be kept entirely free for experimental purposes. For the general work of the laboratory, the Author uses the Davey motor already mentioned (p. 20), and another small vertical engine. Both these are arranged so that they can be indicated and braked, and certain of the simpler test-measurements made upon them.

Gas-Engine.—For experimental purposes, a gas-engine would be an excellent piece of apparatus, for, in spite of all that has been said and written on the performance of gas-engines, complete and trustworthy quantitative trials, carried out by uninterested parties,

[1] "Engineering," vol. xxxv. p. 179.

[2] In "Engineering," vol. xl. pp. 317, 342, is given an account of the Author's method of conducting a trial, and some details as to the use of these forms.

are almost wanting. It is not necessary here to go into more details about gas-engine tests than to say that, to be complete, they involve determinations of:—

(i.) Temperatures of explosion, &c.
(ii.) Quantity of gas, and also quantity of air,[1] used.
(iii.) Distribution of gas in cylinder.
(iv.) Quantity of water used.[2]
(v.) Composition and calorific value of gas.
(vi.) Indicated and brake HP., &c.

No doubt the greatest difficulty—perhaps the only special difficulty—about these tests is the accurate determination of the very high temperature involved. As yet no satisfactory plan seems to have been devised for meeting this difficulty.

Experimental Boiler.

It is so much more difficult to vary the conditions of working with a boiler than with an engine, that it does not yet appear probable that a great deal can be done in this direction in a laboratory. The first essential in a laboratory boiler—with regard, that is, to engine trials—is that it should make dry steam, and the making certain of this appears to involve the use of a large boiler, which of course must be well covered. If there were any way of making the cover removable, most interesting and instructive experiments could be carried out on the wastefulness of working without covering.[3] But good covering appears to be essential to the production of dry steam.

Professor Smith uses, at the Mason College, a vertical boiler, so arranged that a portion of its heating surface can be thrown out of use at pleasure, and with a Cornish or Lancashire boiler this can also be easily done by special arrangements of dampers. Interesting results as to the heating-surface efficiency can no doubt be thus obtained.

Messrs. Bryan Donkin & Co. have lately shown the Author their method of carrying out measurements of the velocity, temperature, quantity, and composition of furnace gases, and although he has not yet had similar measurements made in his laboratory, he believes that they are such as students could carry

[1] Trials made by Messrs. Brooks and Steward in the Stevens Institute of Technology, N.Y., will be studied with much interest by those requiring information on this subject.

[2] Minutes of Proceedings Inst. C.E. vol. lxix. pp. 303–4.

[3] See experiments by the Author in "Engineering," vol. xlii. p. 101.

out with fairly reasonable accuracy of result, if with no absolute exactitude. They do not appear to require more knowledge of chemistry, and capacity for manipulating chemical appliances, than may fairly be expected from a student of engineering.

As to the weighing and measurement of fuel, no remark need be made except that measurements which depend partly upon the "estimation" of fuel on the grate must always be doubtful. If the fires cannot be drawn before and after the trial, it is probably safest to diagram the trial, as was done by Sir Frederick Bramwell and Mr. W. E. Rich in the case of the "Anthracite," and use the average slope of the coal curve as a measure of the fuel used.

Experiments on the evaporative value of different fuels in one boiler are not very instructive, unless the furnace can be altered to suit the very varying conditions necessary to burn each fuel to the best advantage. Such alterations are hardly possible under ordinary conditions. Experiments of this kind, moreover, take up an exceedingly long time, and are in many ways not very suitable for being carried out by students. The measurement of the real evaporative power of fuels, made in a calorimeter, is, however, a matter very suitable for an engineering laboratory, although no doubt it is an essentially chemical operation. The Author has used in his laboratory for this purpose a calorimeter designed by Mr. C. J. Wilson, F.I.C. This instrument is on the same principle as the Thompson calorimeter, but with a number of improvements, which make it not only much handier in use, but much more trustworthy in result.

The boiler now employed by the Author is of the type shown in Fig. 3, Plate 9. It has been designed and constructed by Mr. Lindsay Burnet, Assoc. M. Inst. C.E., of Glasgow. It will be seen that it is a type which may be called locomotive-marine, a double adjective which explains itself. It is made entirely of steel, and is an interesting example of the forms of construction as to flanged plates, through stays, &c., used in the most modern types of high-pressure boilers. The flanging is so arranged that every rivet can be hydraulic-pressed. Special facilities are provided for cleaning the water-space under the furnace and on top of the firebox. The sides of the front shell are embossed, so that the short stays are square with both plates through which they are screwed. It works up to 120-lbs. pressure per square inch, having been tested to 250-lbs. It has very satisfactorily fulfilled all the Author's requirements.

A separate feed-heater of any type may well be an adjunct to an experimental boiler, arrangements being made for the proper

measurement of temperatures, and for shutting it off entirely when required. Experiments in connection with the value and cost of superheating steam may also very well be carried on in a laboratory with good hope of obtaining more definite results than have hitherto been at the disposal of engineers.

The working of an injector may also form a very useful subject of experiment in connection with an experimental boiler. In order really to measure its working, however, it would be necessary to have a second (small) boiler to supply it with steam. There appears to be otherwise no accurate method of measuring the quantity of steam which it uses.

The only one of the boiler-mountings which requires special calibration is the pressure-gauge. It is advisable to compare the indications of the gauge both with the indicator-springs used for the HP. cylinders and with a mercury column. The mercury column is also probably the most trustworthy test for indicator-springs, at least so far as what may be called their static accuracy goes.[1] It is well to have a thermometer in the boiler, to measure directly the temperature of the steam, and the same may be said of the steam-chest.

In order to get accurate feed-measurements, in case the water-level in the boiler is not exactly the same as at the beginning of a trial, it is necessary to have the boiler calibrated about the level of the gauge-glass by weighing water into it. It is also important to know exactly the whole weight of water in the boiler up to any given height in the glass, and the expansion of that water up to the ordinary working temperature of the boiler.

It need only be mentioned further that the two final quantities to be measured in connection with engine and boiler efficiency are (i.) lbs. of water per HP. per hour, and (ii.) lbs. of water per lb. of fuel; and that for purposes of comparison it is necessary in both cases to reduce the actual measured quantities to their equivalent in lbs. of water "from and at" 212° Fahrenheit. This is not unfrequently forgotten in the second case, although it is universally done in the first.

Friction Experiments.

Of the several classes of subjects for experiment in an engineering laboratory originally enumerated, the only other which it is proposed to mention here at any length is friction. Engineers

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[1] See Professor Berndt's experiments at Chemnitz on the accuracy of indicator diagrams summarized in "Engineering," vol. xxv. pp. 77, 294.

are now quite aware that the old experiments upon dry friction, whatever their scientific value, bear no particular relation to the conditions of technical work, and that the so-called "laws of friction," based on these experiments, in no way apply to the friction between ordinary lubricated rubbing surfaces in machines. But there still remains an immense field for experiment in this matter, as will be seen when it is considered how small a part of the following outline has yet been filled up experimentally. For a complete theory of the friction in machines something must be known of the variation of frictional resistance with—

(i.) Velocity:—

(*a*) Velocity-constant, and the same for all rubbing-points (*i.e.* constant and uniform) as in bearings.

(*b*) Velocity-constant, but different for different rubbing-points (*i.e.* constant and non-uniform) as in pivots.

(*c*) Velocity varying in magnitude, but the same for all rubbing-points at any instant, as between a pair of wheel-teeth.

(*d*) Velocity varying both in magnitude and sense, but the same for all rubbing points at any instant, as in guide-blocks or gudgeon-pins.

(ii.) Intensity of pressure (*i.e.* pressure per unit of area):—

(*a*) Total pressure varied, surface remaining constant, as with similar brasses differently loaded.

(*b*) Total pressure remaining constant, surface varied, as with similarly loaded brasses of different chords (*i.e.* with different portions cut away).

(*c*) Pressure varying in magnitude cyclically from instant to instant, as in guide-blocks.

(*d*) Pressure varying in the same way, but in sense as well as in magnitude, as in cross-head pins.

(*e*) Pressure applied (in the case of bearings) on one side or both sides.

(iii.) Contact:—

(*a*) Surface-contact, as with all ordinary bearings, guides, &c.

(*b*) Line-contact, as with spur- or bevel-gearing.

(*c*) Point-contact, as with screw-gearing, or ball-bearings (in the latter, however, the friction may be partly "rolling").

(iv.) Temperature.

(v.) Lubricant:—Each lubricant has a particular temperature at which it works best with any given pressure, and a particular pressure above which it is squeezed out, and becomes useless.

(vi.) Method of lubrication:—

(*a*) Perfect (as by oil-bath).

(b) Approximately perfect (as by pad with ordinary bearings).

(c) Siphon (the difficulty here being to keep the conditions sufficiently constant during any length of time).

(vii.) Nature of material.

This synopsis by no means exhausts the variations of frictional conditions occurring even in every-day engineering, and between rigid bodies, nor does it include any mention of what is generally called "rolling-friction," the determination of which requires different appliances from those used for friction proper.

The frictional resistances of non-rigid bodies are also of great technical as well as scientific importance. Under this head come:—

(i.) Friction of straps, belts, ropes, &c. With this may well be included their resistance to bending round pulleys, the whole matter being in the closest possible relation to experiments on the efficiency of transmission.

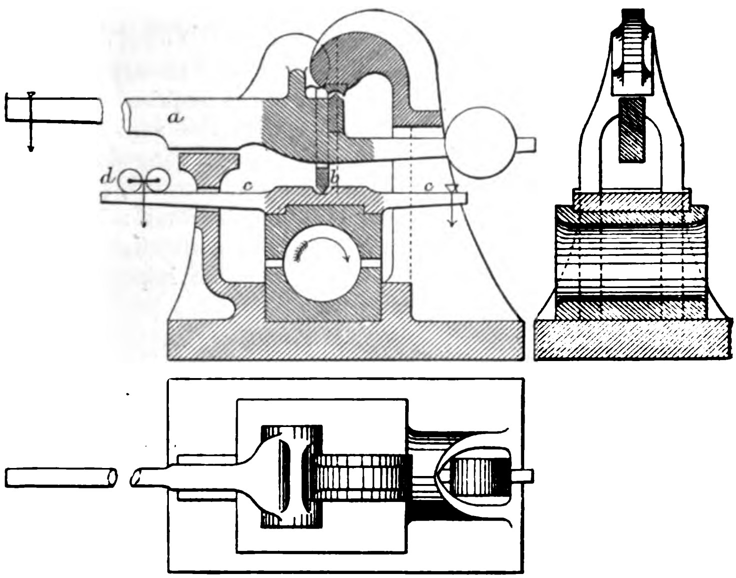
(ii.) Friction of water, air, or other fluids in pipes or otherwise with solid bodies. This is essentially, of course, one of the most important class of hydraulic experiments mentioned on p. 60, and is also closely connected with experiments on ship-resistances.

Professor R. H. Thurston, while at the Stevens Institute of Technology, probably made a greater number of experiments on friction[1] than any other experimenter; but if his results be compared with the list just given, it will be found that they, after all, only begin to cover the ground, and that an enormous field for experimentation still remains. Thurston uses for his experiments on bearings an overhung shaft with a weighted pendulum suspended from it. The shaft is gripped by two half-brasses, one on each side, the pressure being applied by a spring. The frictional moment is measured by the angle through which the pendulum is lifted. Professor R. H. Smith also uses a machine in which the bearing receives pressure from both sides. The pressure is applied by a spring to a 3-inch by 2-inch overhung bearing. A special feature of this arrangement is that the whole weight of the pressure-producing apparatus is taken by a jointed link and completely balanced, the lever which carries it being kept floating during the experiments. The Author has in his laboratory a simple apparatus constructed by Mr. J. Goodman, Stud. Inst. C.E., and used by him in recent experiments. It is of the same type as that used by Mr. Beauchamp Tower, in the experiments of the

[1] "Friction and Lubrication," and "A Treatise on friction and lost work in machinery and millwork." New York (John Wiley and Sons).

Research Committee of the Institution of Mechanical Engineers,[1] but necessarily on a smaller scale. This machine, fixed on the bed of a lathe, and driven by a small separate engine, has given very good results, the experiments made upon it including many under (ii. *b*) above, a matter about which few, if any, data were available. The bearing is here loaded by a half-brass on one side only (as in the Mechanical Engineers' experiments), and not on both sides. The apparatus sketched in Fig. 23 was designed by the Author some years ago for obtaining very heavy pressures on a large bearing without the inconvenience of the heavy weights

FIG. 23.



necessary for direct loading. A single lever *a*, of large mechanical advantage, is used, transmitting pressure to the block through a knife-edge strut *b*. A kind of Morin balance *c* is attached to the upper brass, and kept exactly horizontal by shifting a small poise-weight *d*. The frictional moment is known from the position of this poise.

The particular form of friction-brake sketched in Fig. 21 forms an apparatus which is convenient enough for the determination of frictional resistances at high velocities and under variation of load.

[1] Institution of Mechanical Engineers. Proceedings. 1883. p. 632. Plates 88, 89.

It is unnecessary to say anything here as to the ordinary oil-testing machines, many of which are well known, and some of which may be convenient if not very essential adjuncts in scientific friction-measuring experiments.

Hydraulic Experiments.

Such experiments as those of Professor W. C. Unwin [1] on the resistance of disks rotated in water, or of Mr. Mair on the discharge of water at different temperatures,[2] or those made and collected by Messrs. Bryan Donkin and Salter,[3] on the coefficient of discharge through rectangular orifices, may be cited as examples of the class of hydraulic experiments which are of definite technical as well as scientific value, and which may well form part of the experimental curriculum in a laboratory. The apparatus required does not come under any one general head as with the work hitherto considered, it rather requires to be designed or arranged specially for each set of experiments. In many cases, however, it is of a very simple and easily constructed nature, however minute the accuracy of the observations to be carried on afterwards by its help. Experiments with turbines may form an important part of any series of hydraulic experiments.

Experiments on the Theory of Structures.

It is not likely that much, if anything, new as to the theory of structures can be learned from experiments on models. But models of girders, trusses, arches, &c., made of thin bar iron (say $\frac{3}{4}$ by $\frac{1}{8}$ inch), the different members connected by pin-joints, can be loaded in different fashions, and the stresses in the bars measured and then compared with the calculated values of the same stresses found by diagramming or otherwise. Such experiments are of considerable use from an educational point of view in making visible, in a certain sense, the stresses in structures, as well as in giving confidence in the results of calculation, and for this purpose the Author has used them.

In a similar way the abutment-pressures and bending-moments in continuous girders can be measured, with results of a fair degree of accuracy.

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[1] Minutes of Proceedings Inst. C.E. vol. lxxx. p. 221.
[2] *Ibid.*, vol. lxxxiv. p. 424. [3] *Ibid.*, vol. lxxxiii. p. 377.

The Form and Efficiency of Cutting-Tools.

This is a matter to which Professor R. H. Smith has given particular attention at Mason College; it does not seem to have been systematically worked at in any other laboratory. Professor Smith has devised an apparatus by which the pressure on the point of a turning-tool can be measured with considerable accuracy under various conditions as to depth of cut, feed, and speed. He also informs the Author that he has recently devised an apparatus by which the pressures on the points of planing-machine tools with heavy cuts (say 1¼ by ⅜ inch) can also be measured.

The Efficiency of Machines and of Transmission.

The efficiency of transmission by different forms of gearing, belting, spur-wheels, screw-gearing, &c., is a matter coming well within the province of a laboratory, and one of which the practical importance will be seen to be the greater the more it is studied. The recently published experiments by Messrs. Wm. Sellers and Co.,[1] on the efficiency of spur and worm gearing and of leather belting, illustrate the sort of work there is to be done, and illustrate also the extreme difficulties which there are in the way of obtaining accurate results. Experiments on transmission of power by belting have been recently carried on in the Engineering Laboratory of the Massachusetts Institute of Technology by Professor Lanza.[2]

The measurement of the efficiency of machines is of course associated with the name of Professor Hartig, of Dresden,[3] who has made so many experiments on this matter. In a laboratory it is possible to make typical experiments of this kind, as illustrations of method, but experiments for obtaining quantitative results must practically be carried out in works. In factories alone can a sufficient variety of machines be found working under normal and practical conditions, to give actual numerical value to measurements of their efficiency.

The Action and Efficiency of Pumps and Valves.

The action and efficiency of pumps of various types may well form the subject of experiment in a laboratory, the apparatus

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[1] See Mr. W. Lewis's Paper in Transactions of the American Society of Mechanical Engineers, vol. vii. p. 273; and "Engineering," vol. xli. pp. 285, 363, 581, and vol. xlii. p. 127.

[2] Transactions of the American Society of Mechanical Engineers, vol. vii. p. 338.

[3] Civil Ingenieur, 1877, 1878, 1880, 1881, &c., &c.

required (given the driving power) being simply the pumps themselves, with tanks and water-measuring appliances. The pumps tested must be of small size, but should not be mere models. The action and resistance of pump-valves are in themselves most important matters. The valuable experiments of Professor Riedler on this subject[1] were made upon the valves of the pumping engines of various mines. But the experiments of Professor Bach[2] have shown what valuable results may be obtained from experiments on smaller valves, and altogether on a scale most suitable for laboratory work. It is much to be wished that such experiments may be repeated and multiplied.

The Resistance of Vessels and Propellers, &c.

Scientific experimental investigation in this subject is inseparably associated with the name of the late Mr. W. Froude, M. Inst. C.E. His own beautiful apparatus is now utilized for government work under the direction of his son, Mr. R. E. Froude, M. Inst. C.E. This apparatus was until lately unique, but recently Mr. W. Denny, M. Inst. C.E., of Dumbarton, has constructed a tank in his works with a dynamometer and all the necessary apparatus for the carrying on of similar experiments. It is possible that experiments of this type are too complex, and that their theory has been too little investigated to render the experiments themselves suitable for students. If, however, a private shipbuilder can already find it worth while to undertake such work, it seems probable (the Author speaks, of course, without personal experience in the making of such experiments) that apparatus on the general plan of Mr. Froude's might form part of the equipment of a laboratory. Such simple experiments as would serve to fix the main facts as to the nature of ship-resistances on the minds of students, might well be carried out by many of them, more complex experiments by a few, while now and then an opportunity would occur for original researches of value upon difficult points.

It would not be advisable, probably not possible, that many, or indeed any, laboratories should possess apparatus for all the different kinds of experiments here suggested as suitable, and others that may suggest themselves. The testing-machine and

[1] Riedler; "Indicator-Versuche an Pumpen." Munich, 1881 (Wolf und Sohn).

[2] "Versuche über Ventilbelastung und Ventilwiderstand." C. Bach, 1884 (Berlin, Springer). Zeitschrift des Vereins Deutscher Ingenieure. 1886, Nos. 20, 22, &c.

experimental engine should probably find a place in all, but beyond this different laboratories should not be duplicates of each other, but specialized according to the subjects which are most important to the engineering industries of the district, or which best meet the wants of the class of students who attend them. It will be a long time even with this subdivision of labour before all the educational requirements of the country are fully met.

The Author has had frequent occasion to refer in this Paper to the apparatus and work of his own laboratory. He is very glad to have this opportunity of saying how much he has been indebted in the arrangement of the laboratory, and the design of its fittings and appliances, to the skill and mechanical ingenuity of his late and present senior demonstrators, Messrs. R. H. Willis and A. G. Ashcroft, Assoc. MM. Inst. C.E.

Appendixes are added as follow :—

(i.) Forms for conducting engine trials, referred to on pp. 5 and 54.

(ii.) Description of automatic test-recording apparatus mentioned on p. 31, and shown in detail in Plate 9, Figs. 2.

(iii.) Notes on the principal engineering laboratories in Europe and America, compiled chiefly from information kindly supplied to the Author by the gentlemen whose names are mentioned in connection with each.

The Paper is accompanied by numerous diagrams, from which Plate 1 and the Figs. in the text have been engraved.

[APPENDIXES.

APPENDIX I.

FORM A. [*This form is filled up by the working out of the observations recorded on forms* B *to* G.]

EXPERIMENTAL ENGINE, UNIVERSITY COLLEGE, LONDON.

Date____________ Experiment No.____________

Conditions________________________

Experiment began ___h___ m, ended___h___m. Duration ___h___m.

Boiler press._____lbs. per sq. in. Absolute boiler press._____lbs. per sq. in.

Vacuum______inches.

Total revolutions by counter ___ do. per minute___ per minute at cards___

Barometer____ins. mercury = ____lbs. per sq. in. Cut off nominal____

Cut off actual (mean),______ No. of sets of cards______

H.P. cylinder, p_1 (abs.) = ____ t_1 = ____ p_e = ____ I.HP. = ____

L.P. cylinder, p_2 (abs.) = ____ t_2 = ____ p_e = ____ I.HP. = ____

p_3 (abs.) = ____ t_3 = ____ Total I.HP. ____

Weight on brake = ____lbs.; on adjusting lever = ____lbs. Equivalent weight at radius of___inches,___ lbs. Brake HP. at___revs. p. m.___.

Feed water. Temperature____ Total water from tank____lbs.
Difference in boiler____lbs., Nett-feed____lbs., do. per min. ____lbs.

Trap water. From H.P. jacket, total____lbs. do. per minute____lbs.
From L.P. jacket, total____lbs. " " ____lbs.
Total from jackets ...____lbs. " " ____lbs.
From steam pipe ...____lbs. " " ____lbs.
From jackets, engine not running____lbs. " " ____lbs.

Quantity per minute credited to cylinder walls___lbs., do. to radiation, &c.___ lbs.

Total heat of 1 lb. of steam at boiler pressure (from 32°)____Th. units.
Heat received by each lb. of trap steam ... " ____Th. units.
Internal heat of each lb. of steam condensed " ____Th. units
Heat given up by each lb. of steam condensed____Th. units

Discharge notch____Coeff^t. = ____h = ____(from____observations)

Pounds of water over bay per min.____Injection temp.____

Discharge temp.____Rise____

Pounds of condensing water per lb. of steam ______
Pounds of condensing water per minute ______
Pounds of condensed steam per minute ______

Q = { Heat received per min. by engine steam = ______ Th. units.
„ „ trap steam = ______ Th. units.
Total ______ Th. units.

R = { Heat rejected in condensing water per min. = ______ Th. units.
„ „ in condensed steam per min. = ______ Th. units.
„ „ in trap steam (cyl^r. walls) per min. = ______ Th. units.
„ „ „ „ (radiation) per min. = ______ Th. units.
Total ______ Th. units.

W = Thermal equipment of work done = 42·74 × ______ = ______ Th. units.

Total R + W = ______ Th. units.

Difference {Q − (R + W)} = ______ Th. units = ______ per cent.

Actual efficiency = $\frac{W}{Q}$ ______ = ______ per cent.

	From Boiler Temperature.	From Initial Temperature.
Maximum theoretical efficiency $\frac{t_1 - t_2}{T_1}$	______ = ______ per cent.	______ = ______ per cent.
Rate of actual to maximum efficiency.	______ = ______ per cent.	______ = ______ per cent.

Mechanical efficiency = $\frac{\text{Brake HP.}}{\text{Indicated HP.}}$ = ______ = ______ per cent.

Steam through cylinder per I.HP. per hour, calculated from discharge ______ = ______ lbs.
Trap steam per I.HP. per hour (credited to cylinder walls) ______ = ______ lbs.
„ „ (credited to radiation, &c.) ______ = ______ lbs.
Priming water (from separator) per I.HP. per hour = ______ lbs.
Total = ______ lbs.
Total feed by direct measurement per I.HP. per hour ______ = ______ lbs.
Difference ______ lbs.

Steam from cards per I.HP. per hour:—

From HP. cards after cut off ______ lbs. = ______ per cent. of steam through cylinder as above.

From L.P. cards at release ______ lbs. = ______ per cent. of steam through cylinder as above.

FORM B. [*Observations on this form taken every quarter of an hour.*]

EXPERIMENTAL ENGINE, UNIVERSITY COLLEGE, LONDON.

INDICATOR MEASUREMENTS.

Date_____. Experiment No._____. Barometer Inches Mercury_____. = lbs. pressure per square inch_____

Conditions____

H.P. Cylinder constant (= I.HP. for 10 lbs. pressure per square inch at 100 revolutions) = ________________

L.P. Cylinder constant (= I.HP. for 10 lbs. pressure per square inch at 100 revolutions) = ________________

Hour.	No. of Card.	Revs. per Minute.	High-Pressure Cylinder.							Low-Pressure Cylinder.							Total I.H.P.	Remarks.
			Initial Pressure.			Mean Pressure.			I.H.P.	Release Pressure.			Mean Pressure.			I.H.P.		
			Front.	Back.	Mean.	Front.	Back.	Mean		Front.	Back.	Mean.	Front.	Back.	Mean.			

Cards taken by {H.P. front________ L.P. front________ Entered by________
H.P. back________ L.P. back________

FORM C. [*Observations on this form taken twice every five minutes.*]

EXPERIMENTAL ENGINE, UNIVERSITY COLLEGE, LONDON.

DISCHARGE MEASUREMENTS.

Date ______________ Experiment No. ______________

Conditions ____

Thermometer used for Injection ______________ Do. for Discharge ______________

Duration ______________ Zero reading of Bay ______________ Experiment began ______________ ended ______________

Time.	Temperatures.			Height over Bay.	Vacuum.	Remarks.	Time.	Temperatures.			Height over Bay.	Vacuum.	Remarks.
	Injection.	Discharge.	Rise.					Injection.	Discharge.	Rise.			

Average height over Bay ______________ Coefficient of discharge ______________

Corresponding discharge per minute ______________ lbs.

Average injection temperature ______________ do. corrected ______________

Average discharge temperature ______________ do. corrected ______________

Average rise of temperature of condensing water ______________

Observations taken by ______________

FORM D.—[*Observations every quarter of an hour.*]

EXPERIMENTAL ENGINE, UNIVERSITY COLLEGE, LONDON.

STEAM JACKET MEASUREMENTS.

Date__________ Experiment No.__________

Conditions__________

Average release pressure in L.P. cylinder from cards__________lbs. per sq. in.

I.HP.__________Experiment began__________ended__________duration__________

Time.	H.P. Jacket.		L.P. Jacket.		Steam Pipe.		Remarks.
	Total.	Nett Water.	Total.	Nett Water.	Total.	Nett Water.	

Totals__________

Weighed total__________

Difference__________

Weighed total per I.HP. per hour__________

Observations taken by__________

FORM E.—[*Observations every quarter of an hour.*]

EXPERIMENTAL ENGINE, UNIVERSITY COLLEGE, LONDON.

FEED MEASUREMENTS.

Date__________ Experiment No.__________

Conditions__________

I.HP.__________Experiment began__________ended__________duration__________

Water from Feed Tank.				Water in Boiler.			
Hour.	Reading.	Difference.	Remarks.	Hour.	Reading.	Difference.	Remarks.

Total water taken from feed tank__________lbs. Do. corrected__________

Difference in boiler__________lbs.

Total feed-water used__________lbs.

Feed-water used per I.HP. per hour__________lbs.

Observations taken by__________

FORM F.

EXPERIMENTAL ENGINE, UNIVERSITY COLLEGE, LONDON.

BRAKE MEASUREMENTS, ETC.

Date________________ Experiment No.________
Conditions________________________________
____

Brake radius________ ________radius of balance weight________
Brake constant = HP. for 10 lbs. nett load at radius of________feet at 100 revolutions per minute________
Brake HP.________ I.HP.________ Mechanical efficiency________
Experiment began________ended________duration________

Hour.	Revolutions per minute.	Load on Brake.	Balance Weight.	Nett Equivalent load.	Remarks.
		Lbs.	Lbs.	Lbs.	

Counter. First reading________
Final reading________
Difference (total revolutions)________
Revolutions per minute________

Observations taken by________

FORM G.

EXPERIMENTAL ENGINE, UNIVERSITY COLLEGE, LONDON.

BOILER AND FUEL MEASUREMENTS.

Date________________ Experiment No.________
Conditions________________________________
____

Experiment began________ended________duration________

Time.	Weight of Coal Box.		Difference (Coal used).	Ash collected.	Water Level.	Steam Pressure.	Amount of Opening of Feed Valve.	Remarks.
	Before Stoking.	After Stoking.						
	Lbs.	Lbs.	Lbs.	Lbs.				

Total amount of fuel used________lbs.
Fuel per I.HP. per hour________lbs.
Fuel per B. HP. per hour________lbs.
Fuel per sq. ft. of grate surface per hour________lbs.
Water from feed tank during trial________lbs.
Difference of water level in boiler________lbs.
Priming water from separator________lbs.
Total water evaporated________lbs.
Water evaporated from and at 212° per lb. fuel________lbs.
Water evaporated per sq. ft. heating surface per hour________lbs.

Observations taken by________

APPENDIX II.

AUTOMATIC TEST-RECORDING APPARATUS (PLATE 1, FIGS. 2).

The test-piece A is connected with the spring-piece B by the nut T. On the spring-piece are two clips C_1 and C_2, with capstan heads carrying the rods (brass tubes) D_1 and D_2, which are connected with the saddles E_1 and E_2. As the spring-piece extends, the pin G is caused to roll on these saddles by the silk threads F_1 F_2. The pin carries the pointer H, the end of which traces the curve on smoked glass. K is the frame in which the glass is placed; it is pulled forward by the silk thread K_1, the tension being provided by the weight K_2. The glass moves on slides L L held to the centre of the spring piece by the clip L_1. R_1 and R_2 are pins placed at the points on the test-piece between which extensions are to be measured. They are held against the piece steadily, whilst its diameter diminishes, by the spring clips Q_1 Q_2. Any motion of R_1 is communicated by the links P P to the point N_2 of levers N, pivoted on L at N_1. Any motion of R_2 is communicated by links S S to the sector M_2, pivoted on N at M_3. By this differential arrangement no motions common to R_1 and R_2 can move the sector, which receives only motion due to alteration of distance between R_1 and R_2. The sector M_1 is twice the radius of M_2, so that the extensions as shown on the diagram are twice full size. M_4 is a balance weight for the sectors. S_1 is an arm on S for the purpose of taking the pressure of a spring U, which holds it in place against M_2 and R_2. The links S are connected with the sectors M_2 by wrapping silk cords.

APPENDIX III.

LIST OF THE PRINCIPAL ENGINEERING LABORATORIES IN EUROPE AND AMERICA, COMPILED CHIEFLY FROM INFORMATION KINDLY SUPPLIED TO THE AUTHOR BY THE GENTLEMEN WHOSE NAMES ARE MENTIONED IN EACH.

As far as possible the laboratories in each country are mentioned in the order of their foundation.

ENGLAND.

London.

University College Engineering Laboratory, Professor Alex. B. W. Kennedy. Established in 1878. Now contains as its principal appliances:—

(*a*) 100,000-lb. Greenwood testing-machine (p. 10), with strain-measuring apparatus (Fig. 10 and Plate 1), automatic diagramming apparatus for ordinary (Plate 1), and for elastic (p. 32) tests, &c., &c., and worked by Davey motor and accumulator (Fig. 8).

(*b*) Transverse testing-machine (Fig. 19) for spans up to 5 feet, and loads up to 4 tons.

(*c*) Torsion testing-machine (Fig. 20) up to 4,000 inch-lbs. twisting moment.

(*d*) Cement testing-machine (Kühlmann).

(*e*) Indicator testing-apparatus.

(*f*) Experimental steam-engine (p. 53), and boiler (p. 55 and Plate 1), with tanks and other arrangements for complete calorimetric and brake trials.
(*g*) Journal-friction testing-apparatus (p. 58).
(*h*) Machine-tools sufficient for the making of laboratory apparatus, driven by small vertical steam-engine.
(*i*) Dark room, and photographic appliances.

It is more or less historically interesting that University College, London, was probably the first educational institution where practical demonstrations of any kind on the strength of metals were given to students. The late Professor Eaton Hodgkinson made many of his experiments in a machine at the college, and used the machine in connection with his lectures (1848–1860) on the strength of materials.

Birmingham.

Mason Science College, Engineering Laboratory, Professor R. H. Smith. Established 1882.
(*a*) Experimental steam-engine and boiler (pp. 53 and 54), with apparatus for making complete calorimetric tests.
(*b*) Apparatus for measuring the resistance of cutting tools, &c. (p. 61).
(*c*) Machine for experiments on journal friction (p. 58), with pressures up to 450 lbs. per square inch on each side of pin.
(*d*) Testing-machine for loads up to 9 tons, the loads measured by a spring-balance.
(*e*) Machine-tools, &c.

Cooper's Hill.

Royal Indian Engineering College, Cooper's Hill, Engineering Laboratory. Professor T. A. Hearson. Established 1883 (under Professor W. C. Unwin).
(*a*) Wicksteed 100-ton testing-machine, with Professor Hearson's diagram drawing apparatus (p. 28).
(*b*) Cement-testing machine.
(*c*) Oil-testing machine.
(*d*) Sundry machine-tools, driven by a gas-engine, and a 9-indicated HP. steam-engine.

Bristol.

University College, Engineering Laboratory. Professor Ryan. Established in 1883 (under Professor H. S. Hele Shaw).
(*a*) 50-ton Wicksteed testing-machine, with automatic diagramming appliances designed by Professor Shaw.
(*b*) Thurston oil-testing machine.
(*c*) Apparatus for experiments on wires and springs, the deflection of beams, &c.
(*d*) Gauge-testing apparatus.
(*e*) Gas-engine and machine-tools.

London.

City and Guilds of London Central Institute; Engineering Laboratory. Professor W. C. Unwin, F.R.S. Established in 1884.
(*a*) 100-ton Wicksteed testing-machine (p. 10), with various apparatus for measuring strains (p. 22), automatic diagramming apparatus (Fig. 12), semi-automatic elastic diagramming apparatus (p. 32), &c.
(*b*) Special apparatus for applying different stresses simultaneously.

(c) Cement testing-machine (Kühlmann).
(d) Wire testing-machine (Bailey's) with mercurial column.
(e) Experimental engine (p. 52) and boiler with tanks and other arrangements for complete calorimetric and brake trials.
(f) Apparatus for various hydraulic experiments (p. 60).
(g) Numerous machine-tools, &c.
(h) Dark room, and photographic appliances.

Sheffield.

Firth College, Engineering Department, Professor W. H. Greenwood. Opened in February, 1885.

Besides very complete workshop appliances of various kinds, there is here fitted up an experimental engine (compound condensing) with cylinders 9·5 and 16 inches diameter, and 18 inches stroke, supplied with steam by a Duplex tubular steel boiler, and arranged with tanks, gauges, pyrometers, &c., for complete calorimetric testing. It is intended shortly to fit up a metal &c. testing department; but the arrangements for this are not yet carried out.

Leeds.

Yorkshire College Engineering Laboratory,[1] Professor A. Barr. Formally opened in October, 1886.

(a) 100-ton Wicksteed testing-machine, with hydraulic platform (see p. 19) and means for receiving specimens 10 feet long.
(b) Wire-testing apparatus, for lengths up to 55 feet, with automatic diagram drawing apparatus.
(c) Experimental steam-engine and boiler (see p. 52).
(d) Numerous machine-tools, and other workshop apparatus.
(e) A separate room with apparatus for general experiments in mechanics.
(f) Dark room and photographic appliances.

London.

City and Guilds of London Institute; Finsbury Technical College, Mechanical Laboratory,[2] Professor J. Perry, F.R.S. (established 1881).

Besides appliances for systematic instruction in workshop processes, the college possesses a Laboratory of Practical Mechanics containing, among other apparatus, appliances for experimenting upon the efficiency of various mechanical combinations and of electro-motors; the strength &c. of spiral springs; friction in various forms; the strength and elasticity of wires, of beams and of struts; the strength of cement, &c. Indicator and dynamometer experiments are also made upon the steam- and gas-engines at the college.

A very complete Laboratory is now being erected in connection with the Owens College, Manchester, under Professor Osborne Reynolds, F.R.S., and a large gift of money has just been made to University College, Liverpool, for the purpose of establishing a laboratory there, where it will be under the charge of Professor H. S. Hele Shaw. An Engineering Laboratory is also about to be established in connection with University College, Dundee, under Professor Ewing, who has for some time had an electro-technical laboratory at work.

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[1] "Industries," July 16, 1886.
[2] See the Author's reply on Discussion.

Although the testing and experimental works of Mr. David Kirkaldy in Southwark, opened in 1865, do not constitute an engineering laboratory in any sense in which the expression has been used in this Paper, it is right that they should at least be named here. Mr. Kirkaldy, after much experience in testing with such ruder machines as were formerly available, was the first man to set up and work in a systematic manner a testing-machine powerful enough to deal with the largest specimens, so arranged as to make tests not only in tension, but also in compression, bending, torsion, &c., and at the same time of such a high degree of accuracy that its results have from the first been accepted as of real scientific value. His machine is of the type, devised by himself, described on p. 8, and was constructed by Messrs. Greenwood and Batley for a maximum load of 1,000,000 lbs. At this date, when the practice of testing has become universal, when really accurate testing-machines are by no means uncommon, when the matter is even thought of so much importance as to demand special attention in all important engineering schools, it will be felt that Professor Berndt has not put the matter too strongly in saying: "The year 1865, in which Kirkaldy opened his testing-house in London, marks really an epoch in the development of experimentation on the Strength of Materials."

France.

Paris.

École des Ponts et Chaussées.—As long ago as 1843 there have been here appliances, used in the instruction of students, for testing stones, concrete, cements and building materials generally. It is now hoped that a laboratory for experiments in the strength and elasticity of metals may shortly be established, under the direction of Professor Flamand, but at present no laboratory of the kind exists in France.

Conservatoire des Arts et Métiers.—During the earlier part of Professor Tresca's work here he made a number of experiments on air- and gas-engines, &c., in the "Salle des Expériences de Mécanique." Professor Tresca's celebrated experiments on the flow of solids were also made here. There is, however, no testing-machine at the Conservatoire, nor, apparently, any permanent apparatus for engineering experiments.

Belgium.

Liége.

École des Mines, Liége, Professor Dwelshauvers-Déry.
Experimental engine and boiler (p. 53), erected 1886.
The School of Mines has also an important electro-technical laboratory.

It is only due to Professor Dwelshauvers-Déry to mention that he was one of the first, probably the very first, to recognize the importance of practical experimental work in the education of engineering students. He has advocated this energetically for many years, although owing to various causes, his own laboratory has only very recently been started.

German Empire.

Berlin.

Königl. mechanisch-technische Versuchs-Anstalt zu Berlin, Charlottenburg, in the buildings of the Technische Hochschule. Professor A. Martens. Founded 1871, and (in its present form) 1880.

(a) Werder testing-machine, 100-ton, with Bauschinger's strain-measuring apparatus (Fig. 9).
(b) Marten's testing-machine, 50 tons, vertical, and arranged simply for the tension of round bars, with Marten's strain-measuring apparatus.
(c) Wedding's 40-ton testing-machine.
(d) Rudeloff's testing-machine, with diagramming apparatus.
(e) Small torsion-machine.
(f) Large and small falling-weight apparatus.
(g) Machines for tests of repeated loads, as follow:—
Two machines for repeated tensions, each for eight test-bars.
Two machines for continued bending in changing planes, each for sixteen test-bars.
Three machines for repeated bendings, each for six test-bars.
Three machines for repeated torsion, each for one test-bar.
(These ten machines were those used in Wöhler's original experiments.)
One machine for continued bending in continuously changing planes (for six test-bars).
(h) Three machines for lubricant testing, with complete arrangements for the necessary physical and chemical tests.
(i) Five machines for testing paper, with ditto.
(j) Photographic and microscopic appliances for examination and reproduction of fractured surfaces, &c.
(k) Machine tools for preparation of specimens, &c.

Königl. Prüfungstation für Baumaterialen in Berlin. Dr. Böhme. Established in its present form 1880. Principal apparatus:—
(a) 140-ton hydraulic press for crushing brick, stone, concrete, &c., in dimensions not exceeding 1 metre in height and 55 centimetres square.
(b) Lever-machine for transverse testing.
(c) Lever-machine for tensional tests.
(d) Apparatus for testing drain-pipes, &c., under internal hydraulic pressure.
(e) Complete cement-testing apparatus.
(f) Apparatus for determination of specific weight of building materials.

These two establishments, together with a third, the "Chemisch-technische Versuchsanstalt," form what are called the "Königlichen technischen Versuchsanstalten" of Berlin, whose official organ is the quarterly journal mentioned on p. 3.

Munich.

Kgl. technische Hochschule in München.

(i.) Mechanisch-technisches Laboratorium, Professor Bauschinger. Established in 1871, in effect the first of the great German testing laboratories.
(a) 100-ton Werder machine (Fig. 1), with Bauschinger strain-measuring appliances (Fig. 9).
(b) Machine for repeated applications of load (tension) on Wöhler's system.
(c) Machine for repeated applications of bending stress in changing planes, Wöhler's system.
(d) Plate-bending machine.
(e) Machine for testing wear of materials.
(f) Complete appliances for cement-testing (besides those connected with the Werder machine, p. 41).
(g) Machine tools for preparation of specimens and apparatus, driven by a 2-HP. Otto engine.
(h) Various appliances for the chemical examination of cements, etc.

(ii.) Laboratorium für theoretische Maschinenlehre, Professor M. Schröter.

Organised by Professor Linde in 1876, the first laboratory in which students received practical instruction in complete steam-engine experiments. This laboratory contains the two separate engines mentioned on p. 52, the one condensing and steam-jacketed, with Sulzer valve-gear, the other non-condensing and unjacketed, with Rider valve-gear. The students are first taught the construction and management of indicators, gauges, water-meters, dynamometers, etc., and in a later session have continued practice in the use of such instruments in complete calorimetric engine-trials.

The "Heizversuchsstation" at Munich, under the care of Dr. H. Bunte, deserves mention here, for although standing at present in no direct connection with the Polytechnikum, it yet is an important institution for scientific research in relation to some of the matters mentioned in this Paper. Dr. Bunte's apparatus consists of a large furnace and specially-constructed boilers, the whole forming together a gigantic calorimeter, which he uses for the determination of the values of various fuels and the best methods of burning them. The establishment is more or less officially connected with the Polytechnischer Verein in Munich, and with the Bayerischer Dampfkessel-revisions-Verein. Dr. Bunte's experiments have been published in the "Bayerische Industrie-und Gewerbeblatt," and separately in Nos. 1, 2, and 3 of "Bericht der Heizversuchsstation München" (Munich, Wolf und Sohn).

Chemnitz.

Königl. höhere Gewerbe-schule;—Festigkeits-prüfungsanstalt. The department for testing metals is under the care of Professor Berndt, the director of the Institution; the department for building materials under the care of Professor Gottschalk. The former, founded in the year 1880, contains a 66-ton horizontal testing machine, with an angle lever, more or less of the Werder type, but with screw instead of hydraulic ram.[1] The latter contains a hydraulic press for stone-crushing; apparatus for cement-testing, &c.

Stuttgart.

Materialprüfungs Anstalt am K. Polytechnikum, Stuttgart. Professor C. Bach.

Opened in 1884. Weekly demonstrations are given to students (in connection with lectures on the Theory of Elasticity) in the summer, and in special cases opportunity is given for the students themselves to experiment. The establishment is under the control of the Ministry of Education, by whom all financial and other arrangements are made.

The principal appliances are:—

(*a*) A 60-ton testing-machine of the Werder type, but with screw instead of ram.
(*b*) A 150-ton hydraulic press.
(*c*) A machine for determining the wear of stones.
(*d*) Cement-testing apparatus.

Besides these there are the necessary extension, &c., measuring-apparatus, machine tools for preparing specimens, gas-engine, &c.

The Polytechnikum also contains an important electro-technical laboratory.

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[1] Mittheil. d. Sächs. Ing. u. Arch-Ver. 1879.

Dresden.

Königl. sächs. Polytechnikum.—There is here no engineering laboratory proper, but there is, under Professor Hartig, a technological laboratory in which mechanical and chemical experiments are made on matters connected with paper-making and the textile industries.[1] The work of Dr. Hartig in connection with the mechanical efficiency of machines and machine-tools is well known, and has been mentioned in the text. There is also at the Polytechnikum an electro-technical laboratory under Professor Hagen, and also what is essentially laboratory work in applied kinematics[2] under Professor Rittershaus. The students here, as at some other technical schools on the Continent, make indicator- and brake-tests of engines in neighbouring works.

Baugewerbe Schule.—There is here a testing-machine and other appliances for experimental work under Professor Fritzsche.

Hanover.

Technische Hochschule zu Hannover.

A very considerable amount of experimental work is done here, partly by the students and partly for purposes of scientific research. The apparatus used includes friction-measuring machines of various types, dynamometers, sundry indicators (used on the engines—steam, gas, and water—in the College), anemometers, and apparatus for measuring pressure and velocity of air-currents, and sundry apparatus for hydraulic experiments. The College has also a "mechanico-technological" laboratory (1884) for investigations connected with the strength and other properties, physical and chemical, of paper and textile fabrics.

AUSTRO-HUNGARIAN EMPIRE.

Vienna.

K.K. technische Hochschule. Engineering laboratory under Professor Karl Jenny. In this laboratory the students go through a regular course of training in the practical making of tests of various constructive materials. The principal apparatus is:—

(*a*) A Werder testing-machine of 50 tons, arranged for tension and compression only.
(*b*) A Werder machine of 80 to 100 tons, arranged also for transverse and torsional tests.
(*c*) A 15-ton lever-machine.
(*d*) Very complete appliances for measuring elastic extensions, twists, etc.
(*e*) Apparatus for measuring transverse alterations of diameter of pieces tested in tension and compression.

Prague.

K.K. deutsche technische Hochschule in Prag; Mechanisch-technisches Laboratorium, Professor H. Gollner. Established 1877.

(*a*) Gollner testing machine (Fig. 4), of 20 tons, with special arrangements for reducing leverages for wire-testing, and with Gollner's strain-measuring appliances (p. 25, footnote).

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[1] Das Experiment a. d. Gebiete der Mechanischen Technik (Verlag d. niederöst. Gewerbevereines. Vienna, 1885).

[2] Civil Ingenieur, 1884, p. 23.

(*b*) 70-ton hydraulic press for tests of building materials.

This school also possesses a Laboratory of Electrical Technology (Professor Puluj), and a special laboratory for various technological experiments (some of which have been alluded to in the text) under Professor Kick, some results from which have been published as "Das Gesetz der proportionalen Widerstände" (Leipzig, Felix, 1885).

Buda-Pesth.

K. ungar. polytechnische Hochschule (Rector, Professor Alex. de Lipthay), Mechanisch-technisches Laboratorium, Professor Nagy. Established in its present form 1882.

(*a*) Werder testing-machine, with Bauschinger's strain-measuring apparatus.
(*b*) Hydraulic press for crushing stones, etc.
(*c*) Cement-testing machines, with the necessary physico-chemical apparatus.
(*d*) Machine-tools for preparing specimens, etc.
(*e*) Dynamometers, indicators, etc.

The Polytechnikum contains also numerous and very complete collections of machines as well as models employed in various industries.

SWITZERLAND.

Zürich.

Anstalt zur Prüfung von Baumaterialen am eidg. Polytechnikum, Professor L. Tetmajer. Established in its present form (as an independent annex of the Polytechnikum) in 1880, the Werder machine having been brought to Zürich in 1877[1] and contains:—

(*a*) Complete arrangements for tests of building stones.
(*b*) " " cements, mortars, etc.
(*c*) " " iron, steel, and other metals, and wood.

The principal apparatus consists of a Werder machine, fitted with Bauschinger's measuring appliances, a 120-ton hydraulic press, a Mohr and Federhaff's testing-machine, a cement-testing machine, etc. Special facilities also exist, partly in connection with the Polytechnikum, for chemico-physical work in connection with analysis of cements, stones, and metals.

RUSSIA.

St. Petersburg.

Wegebau-Institut in Petersburg, mechanisches Laboratorium, Professor N. Belelubsky.

As far back as 1853 experiments on building materials were made here with a small (10-ton) testing-machine under Professor Sobko, by the students of the Institution. In 1867 the apparatus was somewhat increased, and moved into larger quarters. Up to 1876, however, the apparatus remained very primitive, and the experiments were practically confined to woods and stones. In 1877,

[1] This particular machine was the first of its kind, and was made in 1866.

under Professor Belelubsky, the laboratory began to be brought into its present condition. It now contains :—

(*a*) 100-ton Werder machine, with Bauschinger's strain-measuring apparatus.
(*b*) Very complete appliances for cement-tests.
(*c*) Hydraulic press for stone tests.
(*d*) Thurston's autographic torsion-machine (Bailey's), etc.

The students take some part in experiments, but without, apparently, going through any systematic course of laboratory instruction. This laboratory is the only one of its kind in Russia.

Sweden.

Stockholm.

Professor J. E. Cederblom informs the Author that the Swedish Parliament has just made a grant towards the establishment of an engineering laboratory at the Polytechnic School here. "The intention with the institution is partly to give the students opportunity to make experiments with their own hands, and partly the purpose of scientific research by the professors." The very notable experiments of Lagerjhelm (1825), were made at the School of Mines (Bergcollegium), at Stockholm, with a 7-ton machine of what was called the "Fuller" type. The load was applied by a hydraulic ram, and measured by weights on a knee-lever.

United States.

Hoboken, New Jersey.

Stevens Institute of Technology, Mechanical Laboratory, Professor Denton. Established in 1876 by Professor Thurston (see p. 2, footnote), essentially for the purposes of commercial experiments, but has been used to a certain extent also for educational purposes, contains—

(*a*) 20-ton Riehle testing-machine.
(*b*) Autographic recording torsion-machines.
(*c*) Fairbanks transverse testing-machine.
(*d*) Autographic transmission dynamometer, etc.
(*e*) Cement testing apparatus (Bailey's), etc.

Boston.

Massachusetts Institute of Technology, Laboratories of (i.) Applied Mechanics and (ii.) Mechanical Engineering. Established 1883. Professor G. Lanza.

(i.) (*a*) Olsen testing-machine (50,000 lbs.) for tension and compression.
(*b*) Beam testing-machine (50,000 lbs.) for taking spans up to 25 feet.
(*c*) Cement-testing apparatus.
(*d*) Apparatus for testing shafting under simultaneous twisting and bending.

(ii.) (*a*) An 80-HP. Porter-Allen engine used for driving machinery in other departments.
(*b*) A 16-HP. Harris-Corliss engine, intended to be fitted up as an experimental engine.
(*c*) Steam- and vacuum-pumps.
(*d*) Machines for experiments on belt tensions.
(*e*) Mercury column.
(*f*) Transmission dynamometer.
(*g*) A number of full-sized machines connected with textile industries.

Ithaca. N. Y.

Sibley College, Cornell University. Mechanical Laboratory. . . . Professor R. H. Thurston. Recently established in its present form.

(*a*) 20-ton Riehle, and other testing-machines, including Thurston's autographic recording torsion-testing-machines.
(*b*) Lubricant testing machines.
(*c*) Dynamometers and Indicators.

The Civil Engineering Laboratory at Cornell also contains testing-machines, and forms also a special hydraulic laboratory for various experiments on the flow of water, &c. Apparatus is also provided here for systematic tests of cement.

Minneapolis.

The University of Minnesota, Testing Laboratory. Professor W. A. Pike. Established 1883.

(*a*) 50,000-lb. Olsen testing-machine, with special appliances for testing beams up to 25 feet long.
(*b*) Cement testing-apparatus.
(*c*) Dynamometer.

The workshop tools are driven by a 35-I.HP. engine, which it is intended to fit up as an experimental engine.

Worcester, Mass.

Worcester County Free Institute.

The practical instruction given here is essentially highly systematized workshop instruction, but the Institute possesses a 50,000-lb. Fairbanks machine in its physical laboratory, with which, since 1879, students have had some actual practice. The students also have practice in the measurement of power by indicators, and brakes, &c.

Cambridge, Mass.

Harvard University, Lawrence Scientific School.

There is here "a 60,000-lb. Riehle testing-machine for metals and limes, and a 1,000-lb. cement-testing machine under Professor W. S. Chaplin."

New Haven, Conn.

Yale College, Sheffield Scientific School.

An engineering laboratory is at present, according to the last official report, in process of formation here.

St. Louis.

Washington University.

A "Laboratory of Applied Mechanics and Dynamic Engineering" has just been started, under the control of Professor C. M. Woodward. The testing-machine is a 100,000-lb. Riehle machine.

New York.

School of Mines, Columbia College.

An engineering laboratory is in process of formation here. The college has a 50,000-lb. Fairbanks machine, and also cement-testing apparatus.

The University of Georgia (Athens), the Vanderbilt University (Nashville), and the State Agricultural and Mechanical College, Ohio, all have Riehle testing-machines of 40,000 lbs. capacity, while the Rose Polytechnic Institute of Technology (Terre Haute, Ind.), and the University of Illinois (Champaign, Ill.), have recently set up 100,000-lb. machines, and the University of California (Berkley) a 50,000-lb. machine of the same type.

Australia.

New South Wales.

University of Sydney.

Professor Warren has here an engineering laboratory with a Greenwood testing-machine (100,000-lb.), accumulator, strain-measuring apparatus (Kennedy), and a considerable number of machine tools and other apparatus. The testing-machine was sent out in 1884.

Victoria.

University of Melbourne.

Professor Kernot is here just starting an engineering laboratory of the same general nature as that at Sydney.

[Discussion.

Discussion.

Mr. Woods. Mr. EDWARD WOODS, President, said that the Author had devoted a long experience to the subject of laboratory appliances, and his Paper was most valuable and interesting, not merely to students but to engineers in general; many engineers, like himself, were glad to avail themselves of the Author's assistance in carrying out experiments upon iron and steel work under their construction.

Professor Kennedy. Professor A. B. W. KENNEDY observed that all who had had to do with the preparation of a Paper containing so much matter that was cyclopædic rather than original, would know how difficult it was to make such a Paper complete. He had done his best, but he should be exceedingly obliged if members would point out any omissions, which he was afraid were numerous, but they were unintentional. In consequence of the length of the Paper, he had felt constrained to limit himself rigidly to the subject-matter of its title; he had therefore been compelled to omit all reference, practically, to three matters. In the first place he had not referred to what might be called educational workshops, of which there were many. The relative value of such institutions, as compared with engineering laboratories, was no doubt a very important matter, but he could not include any description of them in a Paper which professed to deal only with laboratories. Secondly, while he thoroughly recognized the importance and value of what might be called laboratories of applied mechanics, he had omitted them, and he had also made no reference to electro-technical laboratories. It was not that he undervalued either of those classes of institutions, but that it was impossible to deal with them even within the very unreasonable limits that he had already set himself. He wished to supply two omissions. When the Paper was written, he did not know that at the Sheffield Technical School of the Firth College there were not only workshop appliances of a very elaborate kind, but also an experimental engine and boiler, and that a testing laboratory in addition was being fitted up. These were, he believed, under the care of Professor W. H. Greenwood, M. Inst. C.E. The school itself was opened by Sir Frederick Bramwell, about two years ago. He ought also to have mentioned that at King's College, London, in addition to the well-known workshops, there was a testing-machine of the Greenwood type. His Paper dealt especially with experimental appliances connected with educational work of various kinds, not with experimental appliances *per se*. His desire was

Professor Kennedy. that his Paper should really form a peg upon which to hang remarks as to the experience of practical engineers in regard to their methods of carrying out their many experiments. If the discussion should be so extended, it would, he believed, prove a great deal more valuable than the Paper. With the President's permission he would show the members one experiment before the discussion commenced. He had with him a little apparatus designed by Mr. Ashcroft and himself; it was essentially a small testing-machine on the same principle as the diagramming apparatus of Plate 9; but used without any dead-weight measurement of load, and in other ways much simplified for the purposes of demonstration. (Professor Kennedy then showed upon the screen, by aid of the apparatus mentioned and a magic lantern, the stress-strain diagram of a piece of Swedish bar iron, the diagram becoming visible upon the screen as the test of the iron was proceeding.)

Professor Reynolds. Professor OSBORNE REYNOLDS said he was present in the position of a learner, and was himself perhaps as much interested in the work as any one in the room. At the Owens College an engineering laboratory was being erected and fitted up very much after the pattern which the Author had conducted for several years, and already his kind advice and experience had proved of great use. He should say but little in reference to the detailed experiments described in the Paper, although he wished to compliment the Author on the extremely beautiful illustration he had just given, and on the perfection to which he had brought a most difficult experiment, that of exaggerating, and drawing as a diagram the curve of extension within the elastic limits of a bar. The whole extension, before the elastic limit was reached, was so minute, that it required an extreme degree of accuracy to measure it, and yet it was brought into a line, in some of the diagrams given in the Paper, which had a slope of 25°, 30°, and even 40°. That, he thought, was a result which deserved a high place among mechanical achievements. He should like to say a few words with regard to the educational position and importance of that kind of laboratory work. Although there had hitherto been no definite laboratory at the Owens College, there was a workshop and a steam-engine, and there was a laboratory of his own where experiments were conducted, not particularly with regard to the strength of material, but with regard to what might be called the determination of the laws and constants which related directly to the subject of practical mechanics. Those experiments had been conducted for the purposes of research, and only incidentally used for teaching. The Author had stated that he started with the idea of making his

Professor Reynolds.

experiments an instrument of education as distinct from the question of research, and he deserved great credit for adopting that course. He did not know that any one else had taken up the subject from that point of view, and it required no inconsiderable amount of courage to make such a trial. It was all very well to make experiments for research, but it was quite another thing to try and teach by experiments. When a system had been perfected there was nothing more pleasant than to teach experimentally, because it was certain that everything would happen as it was expected—a definite system was being taught; but with new or somewhat uncertain apparatus, and work that was not perfectly straightforward, it was difficult to keep the attention of the student. Hitches would be likely to occur which might afford food for thought to the person engaged, who understood all about the experiment, but which sadly distracted the attention of those who were learning to make experiment itself. And not only so, but the teacher had to devise every detail, and to find sufficient work to occupy the attention of all engaged. The Author had undertaken that kind of work, and had carried it out to a satisfactory, he might almost say a triumphant, issue. No more important step could be taken, in advancing mechanical teaching, than that of inaugurating a successful system of mechanical laboratory teaching. With regard to the expression "engineering laboratory," he might say that it was one which he much wanted many years ago. Since 1872 or 1873 he had been endeavouring to induce the authorities of the Owens College to increase the facilities of illustration and work for the engineering students; but although he had done his best to bring it about he had not succeeded until after the Author had set the example, and he believed that the term "laboratory" had as much as anything conduced to his success. There was a great shyness about establishing a workshop, but the moment a laboratory was talked of, all opposition disappeared. No doubt the term had more correctly expressed the work carried on, and perhaps the aptness of the expression had had something to do with the result. At the Owens College the matter was now in a fair way of progress. A building 80 feet long by 75 feet wide and 20 feet high, with both top and side lights, was nearly finished. Several machines of the best kind had been ordered, and having the assistance of Mr. John Ramsbottom, M. Inst. C.E., and Mr. John Robinson, M. Inst. C.E., and taking advantage of previous experience, modifications were being introduced. A complete start would be made next session of a system of instruction very similar to that adopted by the

Professor Reynolds. Author. There could be no question as to the importance of researches conducted in laboratories of that kind. The whole engineering profession had recognized the work of the Author and others as conferring a great advantage upon the profession; but he was not so sure that its value as a training for would-be members of the profession had been recognized. A great deal might be said in regard to the importance of that kind of training. There were two ways chiefly of looking at it. The objects sought in the engineering laboratory should be to teach students, and particularly to enable them to practice those methods of measurement which belonged to the engineer and not to the artisan. The necessity for a laboratory course, to complete the education of an engineer, had arisen from the institution, which had taken place of late years, of definite mechanical tests both for the strength of materials and for the efficiency of machines. But the object was not solely or mainly to make accomplished experimenters or testers. The revolution which had introduced these tests might be regarded as the result of the scientific education of engineers. It was only by the theory of structures that they were able to deduce the strengths and elasticities of the infinitely various structures, to be met with in practice, from the simple experimental tests to which material could be subjected; and, in the same way, it was only by a knowledge of the theory of the machines that they were able to make definite use of measurements of efficiency. The theory of applied mechanics had been in every particular framed upon more or less definite experimental results, but the only experiments available for this, up to a few years ago, were those carried out by the founders of the science. In the meanwhile the theory of applied mechanics, as embodied in Rankine's works, had been assimilated bit by bit; and the important results to be obtained by the aid of the theory, where definite experimental results were forthcoming, had become more and more evident, until it might be said that there was scarcely an important contract in which definite tests were not specified for all the manufactured material used. Steam-engines were tested by the indicator. It was not improbable that in a few years all machinery might be tested. The testing of materials and machines had become an important part of engineers' work; that importance was steadily increasing, and with it the higher theoretical training to which it was distinctly complementary. The question was being asked, was the mechanical laboratory going to be substituted for other training? It was not, or should not be, a case of substitution. The experimental part, as introduced in a mechanical

laboratory, was a necessary complement to the theoretical teaching, in order that it might be fully appreciated. To teach a theory without having the circumstances, more or less, before the students, was like teaching the language of a country to those who were unacquainted with the things to which the substantives of that language applied. In the mechanical laboratory there was only a small part of the circumstances of engineering; still some of the very highest class of mechanical practice was placed before the student, and that alone gave an interest to the work which more than balanced the time that might be occupied. Professor Reynolds.

Mr. J. H. WICKSTEED remarked that the Author had introduced the use of an accumulator for making tests, and it would be interesting to know something more of his experience in reference to that method. He had referred to the way in which he throttled the water. In order that the test might be conducted steadily from first to last through the variations of resistance of the sample, beginning with almost no resistance at all, he found it important to have the accumulator pressure very considerably in excess of the resistance of the sample, and then to throttle the passage of the water in order that the extension of the sample might be tolerably uniform. He had also spoken of throttling the passage of the water with two valves. Mr. Wicksteed wished to know whether that was an accidental arrangement, or whether the Author had found that he could more successfully make the speed of the inflow of the water uniform by the use of two valves than he could do by the use of one valve. The Author had adverted to the convenience of a horizontal machine, where long specimens were being tested, because the specimen was at a uniform height, which might be made the most convenient height for the observer. But it always appeared to Mr. Wicksteed that it was a point of great importance to put the specimen vertically when making experiments within the elastic limit, because it was surely better to multiply the length of the specimen itself (taking a 100-inch specimen) than to multiply by mechanical gearing the readings taken from a short specimen, say 10 inches long. If a specimen 100 inches long were placed horizontally, it would sag unless it was supported at frequent intervals by balance-weights or some other arrangement, and that would be inconvenient. Then, if there was a sag upon the specimen, in making a delicate experiment of elasticity, there would be great difficulty in separating the extension of the piece that took place through the lifting up of the part that had sagged. If a specimen was dropped vertically down like a plummet, and hung from one of the joints which had been Mr. Wicksteed.

Mr. Wicksteed. designed by the Author, and which he had himself taken the liberty of copying in some of his practice, and if it was brought from a ball and socket-joint, and held on underneath by another ball and socket-joint, it afforded the opportunity of plumbing the apparatus with a plumb line, the axis of the specimen fell through that line, the pull was straight, and the specimen hung down without sag. That, he thought, was a condition under which it was possible to make elastic experiments with the greatest advantage. If so, it would be a pity to encourage the use of a horizontal arrangement, simply because of the extra feature of a hydraulic lift to enable the experimenter to traverse any distance he liked, up and down a vertical specimen. The Author had spoken of the impossibility of proving the sensibility of knife-edges by the use of dead-weights. It was not impossible, and indeed it had been done. The Consett Iron Company, having a vertical machine, had made a large cradle, which had been suspended to the back centre of the machine. The cradle had been balanced with a weight hung from the end of the lever, and loaded with adjusted 56-lb. weights to the extent of 40 tons of actual dead-weight. The monkey-weight had been rested upon the steelyard to balancing point; the reading from the vernier on the steelyard had then been taken and noted, and also in another column the weights put into the cradle, by which means the reading of the steelyard had been checked through the entire range of the machine, and when the whole 40 tons had been upon the machine, the thing was floated, and nothing remained to be done but to add a sufficient weight to the end of the lever to make it move, so that it was possible to tell exactly what friction was upon the knife-edges. It was sufficient to see that the balance was correct, that the apparatus was sensitive, so that it could be moved up and down with the finger and thumb. Although, therefore, the Author's estimate of ½ lb. per ton was a very reasonable one, he thought the degree of sensitiveness might be made a great deal finer than that. The Author was in the habit of reducing the load carried by the carriage that travelled upon the steelyard for delicate experiments. He could not see the advantage of that system. It seemed to him that the nearer a dead-weight was approached the more perfect the experiment was likely to be. For the very finest sorts of weighing the scale-beam was used, a beam with equal arms. The total load was on one side, and the total weight on the other. Supposing, to commence with, a weight heavier than that which had been quoted in his machine, 1 ton, say even 2 tons, he could not see that that weight would be too heavy for testing horsehair or silken thread, because the propor-

Mr. Wicksteed. tions of the levers could be reversed. The massive weight could be made to have a very small ratio of mechanical advantage over the specimen; indeed it might be actually reversed, so that the specimen might have a mechanical advantage over the weight. Instead of reducing the weights which ran along the lever, he would adopt the plan of altering the ratio of mechanical advantage of the lever. Thus if at first the lever had a mechanical advantage of 50 to 1, and did heavy work, if it was wanted to do light work with it, a supporting plate could be brought up underneath a knife-edge that was fixed in the lever in another place, and so arranged that the lever should vibrate upon the knife-edge with a mechanical advantage of only 25 to 1; or it might be even in the centre of the lever, where there was no advantage at all, which would be an equal scale-beam. He thought he saw his way to making a machine, very simply, in which a knife-edge could be brought to bear in the centre of the lever at $\frac{2}{3}$ of the distance, or at $\frac{1}{50}$ of the distance if required. He had gone in the direction of increasing the weight upon the lever to 2 tons, and he believed that the less number of times the weight was multiplied upon the lever into the test-piece, the less would errors be multiplied, and the nearer would be the approach to an absolute weight that could be sworn to. That was the direction in which he was working in a machine now being constructed for Professor Reynolds at the Owens College.

Professor Unwin. Professor W. C. Unwin said that as he had been engaged more or less in work of the same kind, he could appreciate fully how very much labour and skill must have gone to the organization of the laboratory at University College. The Author might well feel proud that he had taken the initiative in introducing that kind of technical instruction in this country, and also that, in an Institution which had not been generally celebrated for its wealth, he had been able to carry out his plans on so large and practical a scale. The first point which the Paper raised was as to the precise way in which a mechanical laboratory was to be used, and the Author had made a point of the fact that he was the first to make students take part in carrying out experiments in the laboratory. He had no doubt that, in introducing that plan, what had been done was best for the students; he was not so sure that the engineering Professor ought to be equally thankful to the Author. He himself found that the amount of supervision and preparation involved placed a burden of considerable care on the shoulders of the Professor. But in drawing a distinction between the laboratories in this country and those in Germany, it

Professor Unwin.

ought to be borne in mind that in the German Polytechnics there was a very large number of students, and possibly it was because of the large number of students that a different method was there adopted. The Author had given a plan of an excellently arranged laboratory, and it would, he thought, add greatly to its value if he would state what number of students, employed in the way which he thought desirable, could be simultaneously and usefully engaged in a laboratory of that kind. He did not mean in demonstrations, or merely taking the maximum number of men who could be possibly employed at each machine; but taking the hazards which occurred in a laboratory of that character, the chances of specimens not being ready, and other accidents, what would be the normal number of men who could well be employed in a laboratory of the size described? Apart from other subsidiary divisions, the Paper might be divided into questions respecting the strength of materials, and the question of dealing with the steam-engine. He would deal only with the former. And first he desired to say a word with regard to the statement in the Paper as to the Watertown machine, to which he thought the Author had hardly done justice. He believed he had seen in American periodicals drawings of the machine so detailed that it would be quite possible to reproduce it in this country if necessary. The Author had spoken of the difficulty of calibrating the Watertown machine. But Professor Unwin thought he had read how, in the initial stage, that machine was tested by dead-weights precisely in the way in which the Author's own machine would be tested, and he thought there was no more difficulty in the one case than in the other, although his opinion was that no testing-machine so little wanted independent calibrations as the Watertown machine. At all events, after carefully studying the details of the machine, he thought that it was not only by far the largest testing-machine in the world, but by far the most accurate; and the only objection which he could see to the use of a machine of this type, in an ordinary mechanical laboratory, was that it would be at least double the cost of ordinary machines. There was another point about which he thought there had been some misconception. The Author had described machines in which the pull at one end was applied by a hydraulic press, and machines in which it was applied by worm-gearing, and he countenanced the idea that worm-gearing was better adapted to elastic experiments, holding the specimen more firmly than the hydraulic press. His experience was altogether the reverse of that. He had found that the hydraulic press held the specimen

Professor Unwin.

in the machine as steadily and as long as any worm-gearing. Of course the movement of the specimen, if held by the hydraulic press, could only be by a leakage at the cup leathers; and the whole leakage of that kind did not, he thought, amount to an ounce in twelve months. He did not think there was a particle of advantage in worm-gearing over the hydraulic press, and, in convenience, no doubt the hydraulic press had the advantage. He had to consider, at one time a great deal, the advantages of vertical and of horizontal machines, and he agreed that for very long specimens the horizontal machine was the best; but the Author had left out of view what he thought was the special advantage of the vertical machine if it was not wanted for testing excessively long specimens. He could test specimens 6 feet 6 inches in length without making the machine cumbrous. The vertical machine had the advantage that, between the knife-edge of the measuring part and the specimen, no slide was interposed. In that respect, if it was not wanted for testing very long specimens, the vertical machine had a distinct advantage. Of course the friction of the slide could be made very small, but it wanted watching. In testing, everything depended upon the accuracy of measurements, and a good deal of the Paper was occupied with a description of the measuring instruments to be used with testing-machines. The Author had laid down, as a sort of rule, that he had not found measurements beyond $\frac{1}{10,000}$ inch to be practically very serviceable. In measuring the ultimate extension of a ductile material, like steel, a carpenter's two-foot rule was accurate enough for the purpose; but in taking measurements within the elastic limit a very different state of things had to be dealt with, and he did not think that engineers generally had any idea how accurate measurements within the elastic limit must be to have any value. Taking a very favourable case, a bar 10 inches long, and an experiment to determine the modulus of elasticity between a stress of nothing and of 10 tons to the square inch, an error of $\frac{1}{10,000}$ inch in the measure of extension would mean an error of 2 per cent. in the modulus. In trying to determine the extension from ton to ton an error of $\frac{1}{10,000}$ inch would make an error of 20 per cent. in the extension per ton, and he thought that was a larger error than ought to be permitted in a measurement if there was any way of getting rid of it. When he went to Cooper's Hill, he had to look out for some instrument to measure strains within the elastic limit, and he thought he was pretty well acquainted with most measuring instruments. Of instruments for measuring within

Professor Unwin. $\frac{1}{10,000}$ inch there were very few which he thought could be used. In some the means of measurement were accurate enough, but the mode of attachment to the specimen was bad in the extreme. He wished to point out why it was that the mode of attachment of the measuring instrument to the specimen was so important. He might take a case, which occurred constantly, where there was a certain amount of curvature in a bar. When the stress came on, and the bar straightened, the straightening of the bar introduced an error. Supposing the bar to be bent to a radius of 50 feet, supposing it to be bent till it made a versed sine of $\frac{1}{80}$ inch in 10 inches (a bar with such a curvature would, he thought, be rejected, but it was not beyond the line of curvatures that might possibly occur), if the bar was measured exactly on the axis, the straightening of the bar would introduce an error of 0·00012 inch. But it was not generally possible to measure on the axis of a bar. The best that could be done was to measure on two points of the surface of the bar. If the two points were on the surface of the bar, then an error would be introduced of 0·001 inch; but usually the measuring instrument was at a considerable distance from the surface. In some cases the measuring instrument was at a distance of 2 inches from the axis, and if that were so the error introduced into the measurement would amount to 0·004 inch. Supposing the instrument to measure to $\frac{1}{10,000}$ inch, an error would be thus introduced of 40 units on the scale. An error of that amount might not at first sight appear very serious, but the whole extension of the bar within the elastic limit was only 0·007, so that by measuring on the surface the error would amount to one-seventh the whole extension within the elastic limit, and measuring 2 inches away from the axis it was half the extension within the elastic limit. Another cause of error was in the mode in which the bar was held in the machine. If the tension did not pass along the axis of the bar, but on one side of it, a curvature was produced by the action of the stress, which falsified the measurements in the same way. Nearly all instruments which he had seen for measuring the extension of test-bars failed in the mode in which they were attached to the bar. Those beautiful and admirable instruments of the Author's, with a lever arrangement, seemed to fail a little in that respect. The first instrument, which he thought really met the requirements of accurate measurement within the elastic limit, was an instrument invented nine or ten years ago by Bauschinger, which the Author had described, an instrument in which an attached piece rotated a smooth roller carrying

a mirror, and by means of a telescope the rotation of the mirror could be read on a scale. From the first Bauschinger appreciated the importance of the influence of that curvature, because he used two mirrors and two rollers, and it was obvious that if the measurements were made simultaneously, the plus error on one side would compensate for the minus error on the other, and thus the errors due to curvature would be entirely, or almost entirely, got rid of. But a difficulty occurred in that case. It was necessary to have two measurements for each extension, to adjust two instruments on the bar, and in ordinary use in the laboratory that was a somewhat difficult matter. The Author had attributed to Professor Gollner the use of a finger with the roller, instead of a mirror and telescope and scale. In the original description of the Werder machines, which contained a description of Bauschinger's apparatus, there was a roller and finger, and in Bauschinger's Papers, at various times during seven or eight years, there were repeated instances of the use of the roller finger, and vernier, with which Bauschinger appeared to be able to read to the $\frac{1}{50,000}$ inch, so that he imagined that the Gollner instrument described in the Paper was really Bauschinger's. Professor Unwin had endeavoured to get over the difficulty of having double readings, without sacrificing the accuracy which Bauschinger obtained; and a series of instruments, which he had placed upon the table, were designed to effect that object. In all these instruments the bar was gripped by two clips, each with two steel points, one point being on each side of the specimen, and the four points being in the middle plane of the bar. Obviously, if from any straining of the bar, or any unequal compression or extension of the two sides, there was a difference of extension or compression on either side, the middle point of the clip took the average readings on the two sides. In one of the instruments these two clips were arranged with a micrometer screw between. There was an extremely sensitive level on each of the clips, and by a set-screw the lower clip was set to be exactly horizontal, and then, by means of a micrometer screw, the upper clip was set to be level. Then the micrometer screw gave the distance between the two clips parallel to each other, and the measurement by the micrometer screw was virtually the measurement of the axis of the bar. In that way the difficulty of the micrometer screw was overcome, which was that different amounts of pressure might be put on the screw, and so differences of reading obtained. By having a constant weight resting on the micrometer screw there was no difference of pressure on

Professor Unwin.

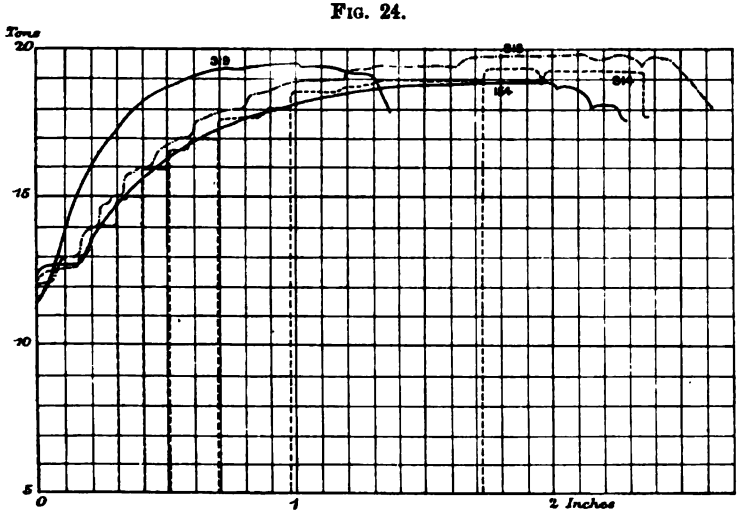
Professor Unwin. the screw. The instrument before him gave readings to about $\frac{1}{10,000}$ inch. In another instrument he had adopted the principle of the roller and mirror, but he had the roller at the centre of the clip, and he had therefore only one mirror. The clips were spaced apart by a distance-piece on a knife-edge, and the centre of the roller was at the same distance from the distance-piece that the centre of the set-screws was, so that the movement of the roller was identical with the movement of the set-screws; thus with one reading the same result was obtained as Bauschinger got with two readings. There was another instrument for measuring the compression of stone, in which the same principle was carried out in another way. The lower clip was attached rigidly by four points to the stone, so that the end of the lower clip had a fixed position with reference to the horizontal plane near the bottom of the stone. The upper clip was attached to two points near the top of the stone, and as the stone was compressed the upper clip moved upward relatively to the lower clip, and the movement could be read by means of a micrometer. He was one of the first in this country to believe in the value of autographic diagrams, in connection with testing-machines, but he was not sure that too high a value was not now being assigned to the autographic diagram. Some persons appeared to have an idea that there was such a thing as an absolute diagram for a material, and that if from the same material two different diagrams were obtained, one of them must be wrong. That was not his opinion at all. Any number of diagrams might be obtained from the same piece of material. Fig. 24 showed a series of diagrams taken with his machine from pieces cut from a bar of wrought-iron. It would be seen that there were four different diagrams, and he did not believe that one diagram was more accurate than another.[1] One was an ordinary diagram for the straightforward test; two others had been taken with four and six minutes' pauses, and a similar

[1] Reduced results for the four bars shown by Fig. 24:—

No.	Tons per Square Inch.		Elongation per cent.
	Elastic Limit.	Maximum Load.	
319	12·97	22·19	34·7
154	14·37	22·10	25·8
313	13·68	22·34	29·5
314	14·23	22·47	28·2

diagram had been taken from a bar half the length of the others. If considerable differences could be produced by pauses of four minutes' duration, it was obvious that that part of the diagram was not absolutely correct. In three cases it would be observed that there was a marked breaking-down point, but in the shorter bar the breaking-down point nearly disappeared. There was nothing essentially characteristic of the material in the extent or size of the breaking-down point. Getting beyond the elastic limit, Professor Unwin.

FIG. 24.



STAFFORDSHIRE WROUGHT IRON.

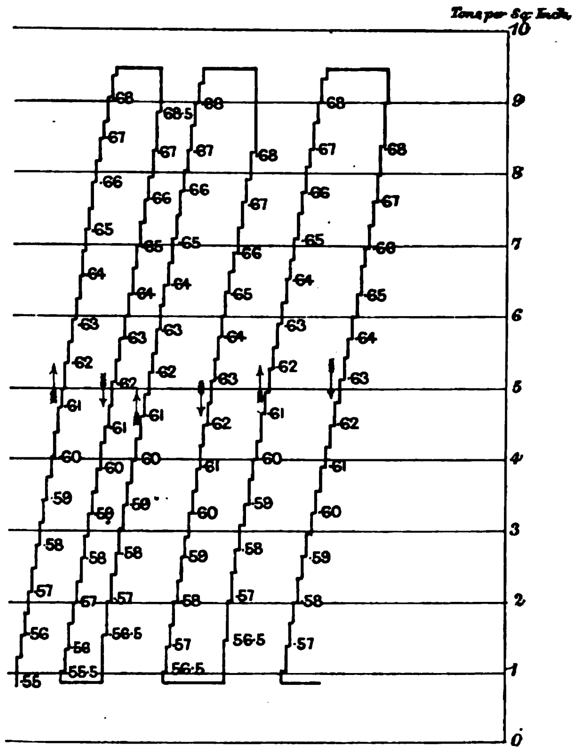
Bar 319, extensions in 4½ inches, the other extensions in 9 inches. Bar 313, four-minute pauses at each ton. Bar 314, load taken off at each ton, and a pause of about six minutes.

he believed there might be very different forms, and the differences might be simply time differences. He thought the tendency was towards the point at which a good deal more attention would be devoted to what happened before the breaking-point began. Hitherto too much attention had been paid to extension beyond the elastic limit, and he thought a time was approaching when extensions which occurred within the elastic limit would be more carefully examined. Unfortunately, under ordinary modes of proceeding, the observation of extensions within the elastic limit not only involved the use of a rather delicate apparatus, but wasted a good deal of time. Fig. 25 was a diagram taken by a machine which the Author had mentioned—the semi-autographic

Professor Unwin.

machine—by which the extension could be telegraphed electrically, and it showed what kind of diagram was obtained. A step was produced at every $\frac{1}{5,000}$ inch extension. The steps could be divided into tenths, so that it was possible to read to the $\frac{1}{50,000}$ inch.

FIG. 25.



Scale ¼.

PLATE OF STAFFORDSHIRE IRON, No. 354.

Area 3·192 × 0·362 = 1·155 square inch. Step at each $\frac{1}{5,000}$ inch of elongations.

Professor Smith.

Professor ROBERT H. SMITH observed that the Paper contained much information gathered from many sources wide apart, and such as would remain always useful to those establishing, and those in charge of, engineering laboratories. Besides information concerning existing laboratory apparatus, it contained many useful suggestions for future development. He had always thought that

Professor Smith.

laboratory work was of prime importance in the college education of engineers, and in his own teaching he had found it very advantageous. The pressure of those non-technical but absolutely essential subjects, viz., mathematics, physics, and chemistry, made it impossible for most students to spend time in the laboratory, to such an extent as to enable them to obtain first-hand experimental knowledge of nearly all matters that they ought to study thoroughly in that way. To the Author's list of subjects appropriate for laboratory study he would add—(1) joints soldered, brazed, screwed, riveted, and pin; (2) hardening and annealing steel and other metals; (3) synthesis of alloys to obtain various degrees of given characteristics; (4) plasticity of metals at various temperatures; (5) strain increasing with time in metals and other substances under heavy stress; (6) earth-pressures; (7) wind-pressure; (8) conduction of heat through surfaces and through plates; (9) the thermal properties of steam; (10) condensation of steam by contact with surfaces. Of these subjects:—(4) was to be studied at the forge by means of positive measurements of forces and strains. (5) was extremely important, and unfortunately very greatly neglected. He might mention the cataract-clock arrangement which was used in his laboratory for obtaining automatically drawn time-strain diagrams. (6) The mathematical investigation of earth-pressures was difficult, and when accomplished seemed very unsatisfactory. It was a very easy subject to experiment upon, and one of extreme importance to civil engineers. (7) was also of the greatest importance, and when the laboratory was provided with a moderately large fan, it was possible to arrange a large number of most interesting and instructive experiments. He had used a method suggested by Mr. Baker for his experiments on the Forth Bridge. (8) (9) and (10) were of course subsidiary to the study of steam- and other heat-engines; but tests of boilers and engines themselves would never supply the detailed experimental information necessary as the basis of the analytical theory of the boiler, engine, and condenser. It was greatly to be desired that special apparatus should be arranged, with which students could experimentally investigate those all-important fundamental laws under the widest possible range of condition, and on a scale sufficiently large to justify the application of the results directly to the practical problems of design. Combustion of fuel ought to be studied most carefully and accurately under the most varied conditions, not on the minute calorimeter scale, but in the furnaces of boilers themselves. For that study a simple and trustworthy pyrometer was very much

Professor Smith.

needed. Of existing pyrometers most were utterly unreliable, and all laboured under the defect that they assumed an enormous theoretical extension of a strictly empirical law, beyond the very short range over which it could be demonstrated by independent experiment. He had been struggling at that problem for several years. He exhibited a pyrometer which had been the result of some years' experiment, and he did so because it had failed. The main idea of the pyrometer was to measure the pressure of a certain quantity of air as the temperature rose. It was a tube to the end of which was attached a pressure-gauge. The volume of the air whose temperature rose and whose pressure rose did not remain constant. The vessel containing the air expanded in consequence of its rise of temperature and the rise of pressure of the air inside. Also, the pressure-gauge had to be kept outside and cool, and it of course contained part of the air. Part of the tube had also to remain cool. Therefore the hot air in the furnace compressed the cooler air in the other part of the instrument, so that the hot air expanded to a small extent. Those furnished three items of correction which practically gave a straight line. The instrument, so far as its indications were concerned, was practically reliable. That, he believed, was the true principle upon which to construct a pyrometer. He had diminished the volume of cold air, to as large an extent as possible, by blocking up the tube all the way down to the hot part, by a rod carefully turned to fit exactly the inside of the tube, a very small groove being cut alongside the rod in order to establish pressure communication between the hot part and the pressure-gauge. Hot joints were altogether abolished, and there was only one welded joint. There was some doubt whether gas did not actually pass through steel at high temperature and at high pressure. The steel of the tube was the densest that could be got—cold drawn steel. After working satisfactorily for some time, the instrument had failed in a mysterious way. It was always cooled carefully and gradually, but it was found over-night that the pressure-gauge had gone suddenly down, thereby demonstrating that some microscopic flaw had suddenly developed, which was sufficient to destroy the instrument. He had not yet obtained any means of getting over that difficulty. He would suggest a pyrometer made of two bars of exactly equal dimensions, laid side by side, bound together at the furnace end, and loose at the cool end, the metals being very slightly different in composition. The difference of elongations, read by the help of a vernier and a microscope, would be taken as proportional to the increase of temperature. The measure-

ments of the strains of a boiler under test, either hydraulic or steam, were of great educational value to students. The hydraulic test was, of course, more convenient for that purpose, because it allowed access to all parts of the boiler. In the chimney there was a mercurial thermometer, the bulb of which lay centrally in a perforated piece of steam-pipe. A very thin sheet of copper was brazed over the perforated portion to protect the closed bulb from direct contact with flame or hot gas. A similar arrangement was used in taking the in- and the out-flow temperature of the surface-condenser. Close to the condenser the pipes were drilled, and pieces of perforated pipe screwed in, the pipes being plugged at the end, covered with thin sheet-copper and filled with mercury. A thermometer dipped in the mercury reached a steady temperature in about a quarter of a minute. He set great value upon the existence of a large 100-ton machine for stress and strain in a laboratory, but if he had to choose between a dozen 10- or 20-ton machines for different classes of tests without the large one, and a 100-ton machine without any small ones, he would decidedly choose the former. One reason for that opinion was that he had no great faith in the practical utility of testing materials to destruction, or even more than, say, half-way towards destruction. Before practical engineering could lay claim to be called scientific, engineers must abandon the barbarous fashion of designing with the help of breaking-stresses, divided by so-called factors of safety. The distribution of stress was, in nearly all structures, extremely complicated and uncertain, and difficult to calculate. He thought that those obscure problems of distribution of stress under moderate average stresses, such as occurred in the ordinary working life of machines and structures, were those which needed most to be attacked in a scientific engineering laboratory. Such investigations would be of incalculable benefit to practical engineering science. The comparison made in ordinary testing-machines between strain and small applied forces was, of course, of fundamental importance; but he could not see any practical utility in finding the breaking-load. More especially was that useless when details as to time-rate at which the load was gradually increased to the breaking-point were not supplied. To find the stress-distribution the strain-measuring apparatus must be of extreme delicacy, and often of great complication. Surface strains might be measured by direct means. He did not know how internal strains could be measured; but he did not despair of satisfactory means of doing so being eventually discovered. His own speculations in the matter tended towards the use of electric or electro-magnetic

Professor Smith.

Professor Smith. apparatus. In Mason College workshop, a good many small testing-machines had been made for various purposes. A Salter's spring-balance, indicating up to 9 tons, was used in one instance, and was quite satisfactory, except that the ordinary rack-and-pinion gearing should be replaced by a fine wire and pulley connection. In a lever machine used chiefly for struts and beams, the lever knife-edge was thrust downwards by a pair of right- and left-hand screws gearing with nuts formed into worm-pinions. Those worms were driven by right- and left-hand worms keyed on the same spindle. By that arrangement there was no end-thrust on the collars of the worm-spindle, and the friction of the gearing was thus considerably reduced. A third machine was used for bending beams up to $\frac{3}{8}$ inch by 1 inch section, the force being measured by a spring, the compression of which was read by means of a vernier scale. That used to be, and perhaps still was, the method used in Sir Joseph Whitworth's works to test the quality of specimens of his well-known steel. Various other machines had nothing special of mention; but apparatus was often rigged up temporarily by the students themselves for special purposes. He thought that those experiments, made without special machines, were quite as instructive to students as those made with elaborate and expensive apparatus. For instance, the measurement of the deflections all along the length of a beam of channel, T or I iron 10 or 20 feet long, and loaded in all possible different ways, was far more educational than the breaking by tension of a bar either large or small. Such a beam placed over different numbers of supports, the pressures on those supports being accurately measured under different systems of loading, gave again a most interesting form of experiment. A large piece of plate- or sheet-iron placed horizontally, supported along various portions of its edges, and loaded in various manners with concentrated and distributed loads, was another kind of investigation attempted by his students, the deflections over the whole surface being carefully mapped out. His students in that sort of work had not infrequently shown a gratifying ingenuity in the construction of the details of the apparatus they had made for their own use. He might instance forms of disengaging-hook for letting fall weights on specimens of material, and means of measuring the momentary deflection of beams struck by falling weights. He exhibited an apparatus for testing pressure upon cutting-tools in lathes. An ordinary tool-holder was extended so as to form a lever, and was pivoted on a small pin in a block clamped in the ordinary tool-rest. In the tool-rest above and

below the lever were placed two parallel strips of steel. These were feelers, and the lever was loaded: the weight of the whole apparatus was carefully balanced by a spring. The weight was moved along the levers until the exact pressure was obtained, as tested by both feelers being equally easy to slide to and fro. By the use of the feelers all chattering was eliminated. If the weight was moved along the lever the least bit too much ($\frac{1}{32}$ inch was sufficient), the lower lever felt tighter than the upper; and if it was not moved along far enough, the upper feeler was the tighter. By that means pressures up to 1,000 lbs. could be tested with an error of no more than 4 lbs. His pupils also tested the frictional efficiency of the different machine-tools in the workshop. A most useful set of experiments made by them had been the statical friction between pulleys and belts. The coefficient of friction seemed invariably to decrease as the pull increased; it was less for leather than for cotton; including the effect of belt-stiffness, the variation of diameter of pulley seemed to have little or no effect with single-thickness leather belts, but with double-thickness the decrease of the size of pulley made a marked difference in the frictional coefficient; and that coefficient increased with the thickness of the belt, other things being unaltered. In a machine he used for testing journal-friction, equal pressures were put on opposite sides of the journal by a strong spring, enclosed in a large iron tube and pushed forward by screw- and worm-gear. The whole of the weight of the apparatus was suspended by a link to the apparatus exactly over its centre of gravity, and that link was pulled upwards by means of a lever, and a weight adjusted until the nicest balance was obtained. The moment of friction was balanced by the two pulls at the two ends of one piece of wire; the one end pulled upwards at 5 inches on one side from the centre of the pin, and the other end of the wire pulled downwards at 5 inches on the other side, passed over a pulley underneath, over another pulley a little further along, then upwards and over a third pulley which was attached to the end of a spring-balance. The two pulls upwards and downwards were exactly equal, and they were measured by screwing up the spring-balance. The equilibrium was tested by the vibration of the lever, mentioned before, and the moment of friction could be measured to within an inch-pound. The specialty of that machine was that no bending-moment was put on the journal. That ensured symmetry, and a probable uniformity of distribution of pressure along the length of the bearing. He might remark in that connection that making

Professor Smith.

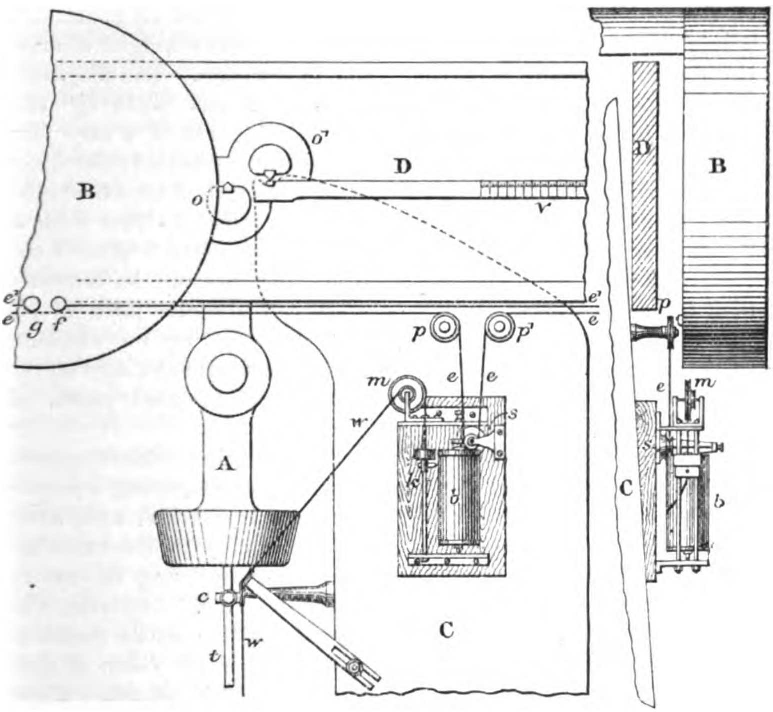
Professor Smith. a machine for testing journal-friction so stiff, that its deflection under any bending moment that might come upon it would be very small, did not eliminate the variation of the intensity of the pressure along the length of the pin, because extremely minute deflection might mean a great variation of intensity of pressure. He wished to make a similar criticism of machines for testing the torsion, stiffness and strength of shafts. A machine of that sort should have all the bending-moment eliminated. With regard to large testing-machines, the only point of advantage he could find, in the vertical over the horizontal design, was that the scale of the former could be tested directly by the application of dead-loads in place of the test-piece. The Author did not explain the method adopted in testing the lever-scale in horizontal testing-machines. In consulting over the design of a 100-ton horizontal machine for Mason College, he was informed that the ordinary practice was to supply extra bell-crank gear to be attached to the test-piece end of the machine for the purpose of this checking of the scale. That seemed to him very unsatisfactory, because the accuracy of the test would then depend upon the correct measurement of the dimensions of the auxiliary bell-crank lever; and it seemed as rational to rely upon careful measurement of the dimensions of the levers of the machine itself, as upon that of the similar sizes of the auxiliary lever. It was decided that a better plan for testing the scale would be to use a spring, previously calibrated carefully by the application of dead-load. If the decision were right, did it not follow that the best type of horizontal machine would be one in which a powerful spring would be the means of measuring the force? Such a spring could be made for a 100-ton force, and could be made compound, so as to give a large scale of deflection for small forces, and a small scale for large forces. The spring would be calibrated up to its maximum force in a single-lever vertical machine like Wicksteed's. Time did not permit him to do more than refer to a rotary transmission-dynamometer, which he exhibited; to two new forms of friction-brake dynamometer; and to the appliances and methods used in connection with his experimental boiler and engine.

Professor Shaw. Professor HELE SHAW said that allusion had been made in the Paper to a form of apparatus for drawing diagrams of stress and strain, designed some time ago by himself; and the Author had truly said that it was in its essential principles identical with those of Mr. Aspinall and Professor Unwin. There were, however, certain features of novelty about it which might make a brief description of it interesting to the members. With this view, and

because no account of it had hitherto been published, he had prepared a front and a side elevation of it (Figs. 26 and 27), by means of which its action could be easily understood. Fig. 26, the front elevation, showed a portion of the Wicksteed single-lever testing machine to which it was attached. The apparatus consisted of a cord attached at the two points *g* and *f*, to the jockey-weight B. Otherwise the cord was endless. It passed round a

Professor Shaw.

FIG. 26. FIG. 27.



Scale $\frac{1}{12}$.

pulley at one end of the lever D, and then round a pulley *p*, and finally, by means of another pulley *s*, on the axis of which was a worm, it turned the barrel *b*, which held the paper on which the diagram was to be drawn. The cord then passed away and went to the other end of the lever, and came back to the other point of attachment. Thus, inasmuch as the position of the weight on the lever gave the exact measure of the force on the specimen, by means of a scale *v*, the distance turned through by the barrel was

Professor Shaw. directly proportional to the stress on the test-piece *t*. The strain was recorded in the usual way, one end of a wire, *w*, being attached to one of two points on the test-piece, passing over the pulley *c*, and finally to a small pulley on the same spindle as the large pulley *m*. Another wire passing over the larger pulley *m* carried the recording pencil *k*, tension on the wire being maintained by a suspended weight shown above *k*. There were thus two motions at right-angles to each other, the motion of the barrel about its axis, which gave a measure of the stress, and the motion of the pencil up and down, which was the measure of the strain. The side view, Fig. 27, showed how the jockey-weight cleared the apparatus, and showed the barrel in position. The diagramming apparatus was extremely simple; it was made by the students of University College, Bristol, at a cost of a very few shillings. It might at first be thought that the possible stretching of the cord might lead to an incorrect result; but no one would think so when reminded that the cord travelled 15 feet with a 6-inch travel of the barrel, and therefore any possible error from this cause was reduced thirty times by that means. As a result of a large number of experiments, he had absolute faith in its records. There was no arrangement for measuring the absolute motion of the whole test-piece. He had not detected any movement of the kind, and it was not measured in most pieces of apparatus of that kind.

The Author deserved the thanks of the whole engineering profession for what he had done in the direction of securing a proper recognition of the value of engineering laboratories; and, after some experience, Professor Shaw wished heartily to endorse what he had said as to the true function of an engineering laboratory being the education of the students themselves. Any one, who had taught the average engineering student to make measurements for the first time, would be convinced of the value of such instruction as a well-conducted laboratory could afford. There should be a happy mean, between the entire devotion of the Professor and advanced students to original work, and a stereotyped process of making measurements and calculations. He was at a school where surveying was taught, and there was a large bare piece of ground on which the field-work was done, and instructions were always given for the poles to be put in the same holes, which saved a good deal of trouble to the teachers and also to the boys, for they had in addition, for the purpose of facilitating calculations, a traditional book handed down to them. He thought that kind of thing might happen in an engineering

laboratory without careful watching and attention on the part of the Professor. Professor Shaw.

When he was appointed to the chair of engineering at Liverpool a year ago, so convinced was he of the importance of an engineering laboratory, that he immediately began to ask for money to establish it, pointing out that without such a laboratory there was no possibility of establishing an engineering school. Now, thanks to the munificence of one of the citizens of Liverpool, there was about to be built a structure, with equipment, which would cost £15,000. In conclusion, he would only direct attention to a long and valuable monograph, by Captains Denizeau and Lechien, on machines for testing metals.[1] It had been abstracted and printed in the Minutes of Proceedings,[2] and would be found of use to those working on the subject.

Professor ARCHIBALD BARR thought that the method of working laid down in the Paper was practically perfect, except perhaps that a little more attention might be given to original work on the part of the most advanced students than was suggested. As to the different testing-machines, he thought that there was very little choice, between the Wicksteed and the Greenwood machines, with regard to accuracy and convenience for ordinary purposes. In considering the suitability of those machines for the Yorkshire College laboratory, he was very much influenced by the circumstance that had the Greenwood machine been adopted, it would have required to have been placed down the longest stretch of the laboratory, and across the cart-way entrance; whereas the Wicksteed machine could be more conveniently placed, and only occupied a space of about 3 feet square upon the main laboratory floor. He also thought that, for teaching purposes, it was of considerable importance to have the specimen exposed to view, during a test, as clearly as possible to a large number of students. That object had been secured in the machine at the Yorkshire College more than it could usually be in the case of the Wicksteed machine, because it had been possible to place the pumps out of the way on the floor of the lower laboratory. The Author had made some remarks with regard to the position of the scale in horizontal machines. No doubt it was very important to have the scale upon a level with the eye; but he might point out that in the Wicksteed machine, the scale being very much longer Professor Barr.

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[1] "Monographie Raisonnée des Machines à essayer les Métaux." Mémorial de l'Artillerie de la Marine. Vol. xi. (1883) p. 311, and vol. xii. (1884) p. 17.

[2] Vol. lxxvii. p. 390, and vol. lxxx. p. 352.

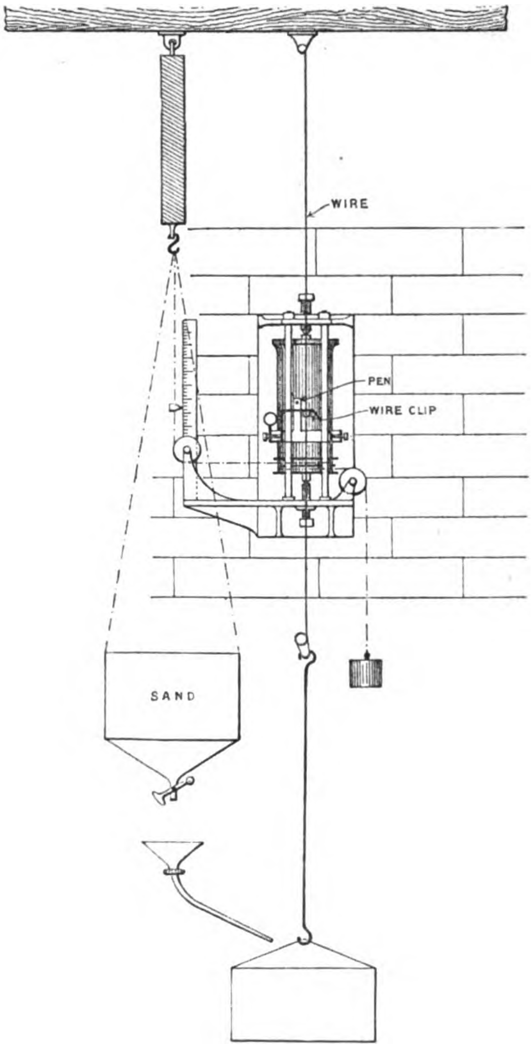
Professor Barr. than in the horizontal machine, the defect referred to was to a large extent counteracted. With regard to the special features of the Yorkshire College machine (p. 19) the machine had been constructed of exceptional height, principally with a view to the testing of long specimens in tension, not with regard to tests in compression, as the Author seemed to think. He considered that it was especially for tension tests of long specimens that the vertical had an advantage over the horizontal machine, on account of the avoidance of the sag of the specimen. In that respect he differed from Professor Unwin. With regard to testing long struts, he thought that the weight of the strut itself would in many cases materially influence the buckling, though in many other cases the amount of that influence might be neglected. Professor Smith had spoken of the value of testing within the elastic limit as compared with testing to breaking. Professor Barr desired to express his opinion strongly on that point. That was one reason why he would say that a machine should be made to take in long specimens. By testing a specimen 100 inches long measurements of a tenth part of the delicacy required in a 10-inch specimen would be sufficient; or, making the measurements as delicately, the results would be ten times as accurate as those obtained from the small specimens. That, of course, had reference only to scientific testing. As to the work to be done in a testing-machine, it was necessary to remember from the outset that there were two purposes for which tests might be made. One purpose was to determine the qualities of a particular specimen of material, the other was to determine the characteristic properties of a material. With regard to testing for the purposes of instruction, it was of very slight importance indeed for a student to know that a particular specimen of steel sent in upon the 10th of January by John Smith and Co. behaved in such and such a manner. What it was really necessary to instruct the student in, was the characteristic properties of materials, and the effects of different kinds of treatment upon them. In regard to initial stresses in the material, the form of the piece, and the method of loading, any test made in a laboratory would have only a very remote connection with what occurred in general practice. A small specimen, for example, cut out of a connecting-rod was a different thing from a connecting-rod with its welds, and so on. The results, therefore, of any one test such as those given in Fig. 11, gave a great deal of information which was not characteristic of the material, but characteristic of the particular specimen tested, of its particular form, and of the method of applying the load. In that con-

nection he differed from what the Author had said with regard to wire-testing. He had compared wires with ordinary specimens. Professor Barr should make the comparison the reverse way. In the case of some wires—annealed wires, for instance—if they differed from an ordinary specimen it would be in their having greater homogeneity. Wire-testing had the further great advantage that a large number of practically identical specimens could be tested. In testing with a small machine represented in Fig. 28 (p. 106), different wires cut from one coil, if two drawings were made upon one paper under like conditions, with a fine pen, they often agreed so closely that one line was for a considerable part of the length not distinguishable from the other. Another advantage was that any particular condition might be varied; the wire could be tested quickly or slowly, Figs. 29 (p. 107), and where a considerable difference was found it would be known that was due to the method of testing. The material might be given rests, Figs. 29, more conveniently than could be done with specimens in a large machine. Besides that, in testing wire, experiments could be made which were practically impossible, or very troublesome, in a large machine. For example, the stress might be applied at the rate of a ton per square inch per hour, or per month. The results obtained were exceedingly interesting, because it was certain that almost the whole of the measurable difference of results on the diagram was due to the different treatment, and not to any difference in the specimens themselves. For that reason he thought that a great deal of valuable information could be obtained from testing wire. With regard to torsional testing, he had made some experiments with an improvised machine, and they had been very interesting because the machine could apply the twisting moment in both directions. That, he thought, should be a characteristic of every machine for scientific work in torsional testing. He had found that by twisting a rod continually in one direction its elastic limit could be raised three or four times as high as by twisting it backwards and forwards. That had a great bearing upon the recent work done by Wöhler, Bauschinger, and others. Very valuable information was to be obtained by tests of that kind. Fig. 30 (p. 108) represented Denison's testing-machine for light loads. The upper part *a* of the standard carrying the steelyard was raised by means of a screw, worm-wheel and worm, actuated by the hand-wheel *e*; the rod *d* was attached to the rear pivot of the steelyard and rose with it, exerting an upward pressure upon the centre of the specimen *g*, which was a cast-iron bar 2 inches by 1 inch, held at points 3 feet apart. The free end of the steelyard

Professor Barr.

Professor Barr.

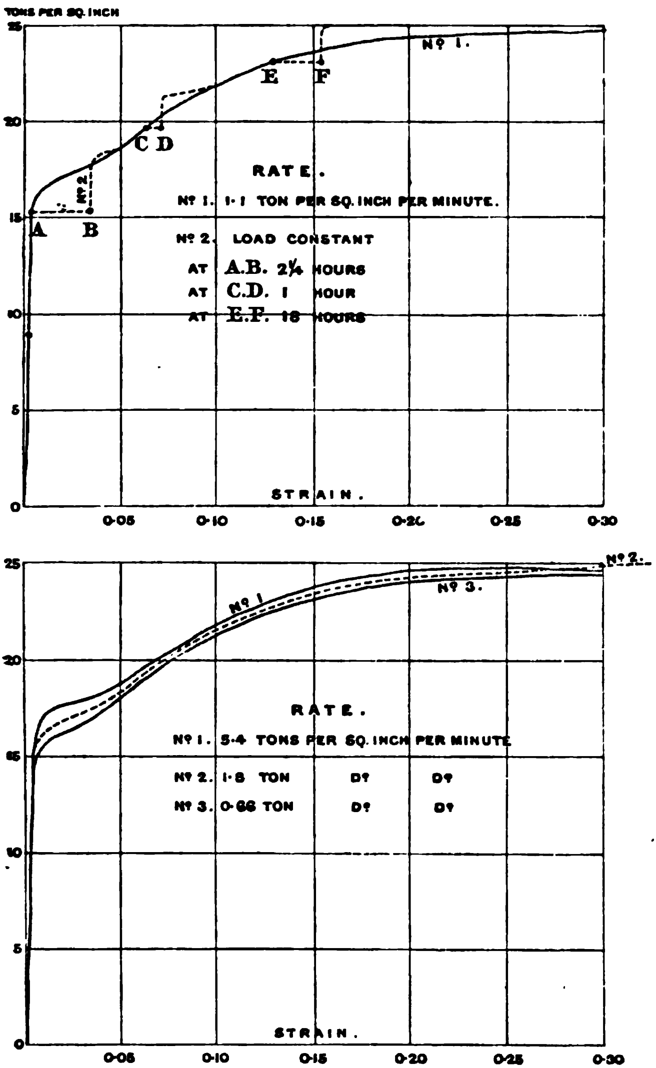
FIG. 28.



WIRE-TESTING MACHINE.

Professor Barr.

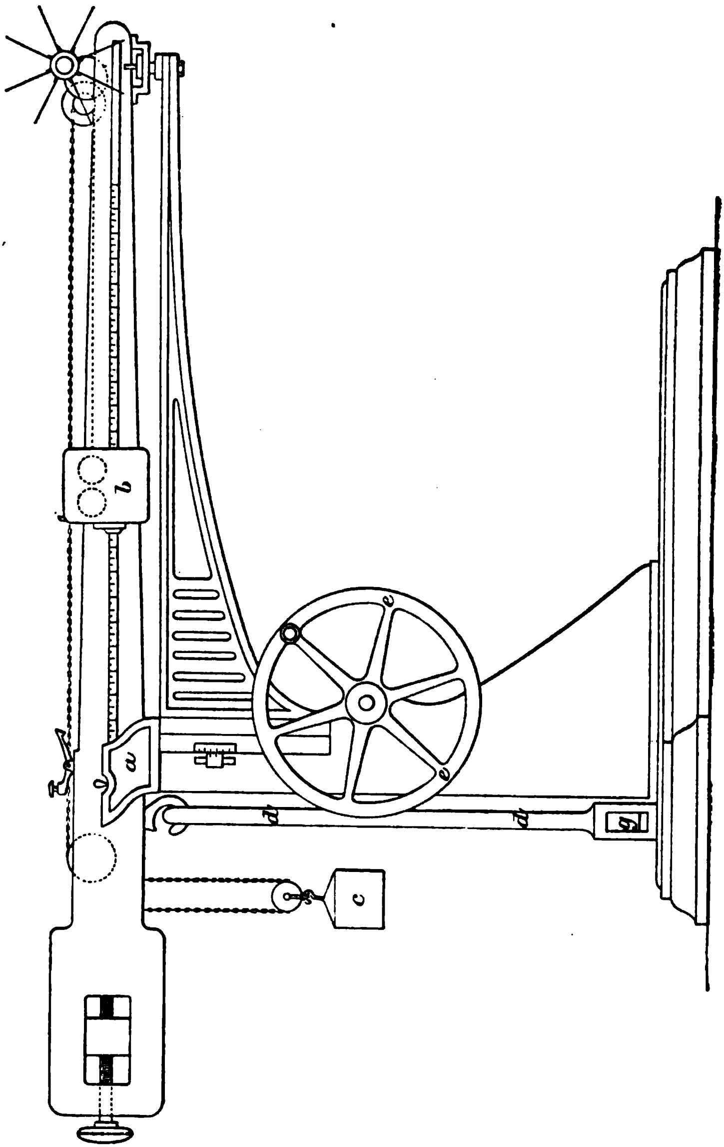
Fig. 29.



Charcoal Iron.

Professor Barr.

Fig. 30.



Denison's Testing Machine.

carrying the detent wheel was thrown up, disengaging the detent Professor Barr. and allowing the counterpoise *b* to run outwards under the influence of the chain and weight *c*. When the increased load caused the specimen to bend, the steelyard fell again to the position of detent and more stress had to be applied by means of the hand-wheel before the weight *b* travelled further upon the lever. The adjustment of the poise was therefore to some extent automatic.

He wished to add one or two remarks upon engines. As to surface-condensing, a variable quantity of circulating-water should be arranged for, and that could not be easily done if the circulating pump was used. Varying the area of condensing surface would also be very valuable, and varying the air-pump volume would certainly be useful. At the Yorkshire College the experimental engine had been arranged in such a way that the stroke of the air-pump was variable while the lowest volume of the pump was always the same, so that there was no discharge during the alteration except that due to the amount of condensation. The stroke could be varied in a few moments while the engine was running, and two diagrams could be taken almost at the same time with different effective volumes of air-pump. With reference to § (x), p. 47, he thought that instead of altering the clearance-volume by additions to the cover, it would be better to do it by additions to the piston; there would then be a still more close agreement between the conditions of radiation in the two cases. Fig. 31 and Fig. 32 represented two brakes which he thought were comparatively simple; Fig. 31 was sometimes called Carpentier's brake and sometimes Thomson's. It was shown by Professor Thomson to his class some years before it was published by Carpentier, and it was used at the Glasgow Gas Exhibition (1880) for testing on the very day on which a description of it was published in this country.[1] He believed it was the only brake which could apply an absolutely uniform resistance. If the friction was too great the loose pulley was drawn round, unwinding a portion of the rubbing cord from the running pulley, and thus automatically adjusting the resistance. The result was that two weights could be put on, and the brake would work under them for any length of time. He had made experiments with the brake up to 9 HP., using weights of 576 lbs. and 366 lbs., running at 148 revolutions per minute upon pulleys 3 feet in diameter. The brake shown by Fig. 32 was only a slight modification of a very well-known one, the modification consisting in attaching to the ropes wooden connections that passed

[1] Minutes of Proceedings Inst. C.E. vol. lxiii., p. 404.

Professor Barr. down the side of the brake wheel and prevented the ropes slipping off. The friction of these was, of course, measured because it was transmitted to the cords just as if it were between the cords and the pulley. The brake could be improvised in any workshop in a few minutes, and at the cost of a few shillings. He had used such a brake with 156 lbs. at the heavy end and only about 12 lbs. at the other end, and the variation of the reading of the spring-balance might almost be neglected. The Author had spoken of

Fig. 31.

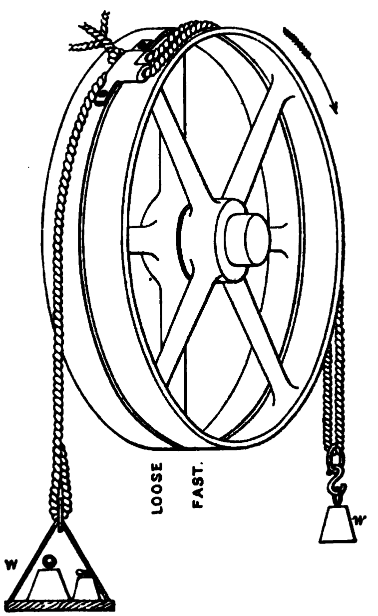
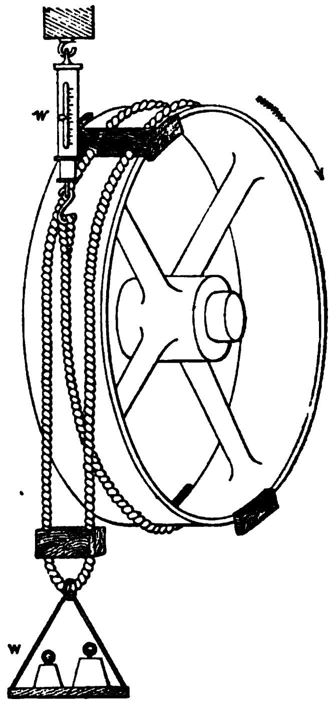


Fig. 32.



the convenience of having two engines. With the Yorkshire College engine it was possible to work either cylinder independently, so that one engine could be under test as a single-cylinder engine while the other was driving the machines. That proved a quite convenient arrangement so far as it went.

Mr. Roberts-Austen. Mr. W. Chandler Roberts-Austen said that if engineering had not so distinct a metallurgical side, it would hardly be possible for a Professor of Metallurgy to speak upon the Paper. Moreover, mechanical tests of metals and alloys were comparatively value-

Mr. Roberts-Austen.

less, unless taken in conjunction with the chemical composition of the material tested, so that the relation between the chemist and the engineer was very close. The system which the Author had inaugurated had taken very firm hold of national education. As to the mechanical teaching of young engineers he could speak with very little knowledge, and less experience, because the wants of the students who came to him at the Royal School of Mines were satisfied by enabling them to use a testing-machine represented in Fig. 4, p. 11. But he had a strong opinion as to the great importance of the kind of work advocated by the Author. So strong was it that for many years past he had tried to make metallurgical teaching and mining engineering practical, in the sense that the Author made the teaching of mechanical engineering practical. The result was that, at the School of Mines, the student might have 1 ton or 2 tons of ore given to him, and be told to extract all the metals which it contained. He might find out what were the best methods to employ, and suitable plant was given to enable him actually to extract the respective metals. There was a blast furnace, a reverberatory furnace, a pan amalgamator for silver ores, and a small Bessemer plant. The Americans were devoting most anxious care to the formation of such mechanical and mining laboratories, and the students dealt with ore varying up to 2 tons in amount, according to its kind. He would direct attention especially to the valuable Paper appearing in the Transactions of the American Institute of Mining Engineers, in which Professor Richards of the Massachusetts Technical Institute, at Boston, had pointed out that there were in America no less than thirty-five engineering laboratories more or less resembling those advocated by the Author, and seven mining laboratories. One great value of the Paper under discussion consisted in its removing entirely all misconceptions as to what a mechanical laboratory really should be. It was not long ago that such statements as these were met with: "We must throw out of consideration altogether the toy-workshops of the schools themselves;" "It is a delusion to suppose that requisite mechanical knowledge can be gained in the workshops attached to some of the colleges." "It can no more be learned there than the execution of engineering undertakings can be mastered except by actual experience." "The construction of toy engines with india-rubber pipes and soft solder, and the turning of dinner napkin-rings . . . . may be pleasant amusements, but little or no actual knowledge is obtained in the use of tools, the properties of materials, or the business of the mechanical engineer." If the Author would carry his

Mr. Roberts-Austen. mind back twenty years, when they were both students at the Royal School of Mines, and would think of the facilities which existed then, and the absolute impossibility of getting anything like adequate mechanical instruction, he would have abundant reason to be satisfied with the progress which had been made, and with his own share in that progress.

Mr. McGregor. Mr. JOSIAH MCGREGOR observed that he had had occasion to study in an official capacity the training of engineers. He cordially agreed with the Author that it was essential for a young engineer to obtain his practical training in the workshop. He could not, however, follow the Author in his next remark, "But the practical training of the workshop is incomplete even on its own ground," as he believed the training of the workshop was remarkably complete, so far as it went, and much more complete than the training usually obtained in engineering laboratories. The Author went on to say, with reference to the laboratory training advocated, that it "should at the same time supplement and complete workshop experience without overlapping it." In what way it could complete workshop experience he was unable to conceive; it might go a small way towards completing an engineering education, but it was not essential to it, like mathematics, mechanics, and other branches of science. To consider an engineering laboratory as in any way supplementary to a workshop was, he thought, absurd. It was really supplementary to a physical laboratory, to which it was closely allied. To associate engineering laboratories with workshops, in this way, he considered a great mistake. The less a laboratory savoured of a workshop the better. The Author asserted that, in an ordinary pupilage, a young engineer had not much opportunity of studying the physical properties of steel, &c. He supposed by the word "pupilage" here was meant apprenticeship. Now, in an ordinary apprenticeship, a young engineer, especially if he went into two or three different shops, had a great deal to learn, which in its way, and as far as it went, was pretty thoroughly taught; and it went at least some way towards giving a knowledge of the physical properties of steel, &c. But in addition to this, which was the essential training of a skilled mechanic, a young engineer must be well trained in the scientific principles of his profession, which training was usually obtained at some of the numerous scientific institutions throughout the kingdom. A good engineering education thus took a long time to acquire, perhaps longer than the education for any other profession, and the essentials of this education were scientific knowledge on the one hand, and practical training in workshops on the other. Where

was this system of laboratory training to come in? He thought Mr. McGregor. it might be safely said that it would not be allowed to interfere with, or diminish the period of, apprenticeship. Therefore it must be accomplished in the period allotted to scientific training, which, if limited as was almost invariably the case, meant substituting it for some of the other more or less essential subjects that should be taken up; and as a laboratory class necessarily occupied a large amount of time, it would in most instances involve a session to itself, that he considered would be much better spent elsewhere. The Author advocated this system of laboratory instruction "for teaching the art of making experiments." This it might assist in doing; but an engineer possessed of the scientific knowledge, and remembering the nature of his practical every-day life, should have little difficulty after perusal of similar experiments, in conducting with the greatest accuracy ever likely to occur. He also advocated this system, to set the student free from the "thraldom of the engineering pocket-book;" but Mr. McGregor believed that the student, who devoted the time thus occupied to ordinary class pursuits, would be in a greater measure free from this thraldom. The engineering laboratories of the Continent were mostly in this respect based on a better principle; they were practically for the use of the Professor, and were used by him for investigation and original research, for which the whole of his time not required for lecturing was available. Being in possession of a laboratory, he was able to illustrate the subject of his lectures, and even to conduct experiments before the students, in quite as effective a way, and with infinitely greater expedition than if they performed them themselves. He considered the Author was incorrect in stating that the object of such a laboratory was "to give the students the opportunity of experimenting for themselves." It should rather be to enable the Professor to bring his subject forward more impressively, as well as to enable him to keep in the fore-front of his profession. No one was more alive to the advantages to be derived at physical laboratories than himself; but to be in a position to derive this advantage necessitated great scientific knowledge, and a comparatively matured judgment, without which it was a great mistake, as well as a waste of time, as it threw away opportunity for ordinary class study at college, which would be invaluable.

Mr. E. A. Cowper observed, in regard to the Author's mode of Mr. Cowper. "causing young men to obtain knowledge for themselves," that he was entirely at one with him, for he believed that the know-

Mr. Cowper. ledge obtained by making experiments and observations was far more useful and enduring than a lecture. A simple chemical fact would illustrate his meaning. If a piece of phosphorus was put into hydrogen gas it produced no particular effect upon it; but if the phosphorus was placed in a medium where the hydrogen was being evolved, the nascent hydrogen absorbed the phosphorus, and became a part of it, and the product was phosphuretted hydrogen. So if a young man discovered a thing for himself, say the details of, and practice with, an indicator, he was no longer one who had simply heard a lecture on an indicator, but he was an "indicator man." His late father, Professor Cowper, at King's College, was always trying to instil into the minds of the men habits of close observation, just as the Author expressed it in different language, the "power of accurate measurement." In a chemical laboratory it was essential that the students should work, and it was just as important in an engineering laboratory. He would be willing to leave the matter there, but as he had had opportunities of trying experiments on a large scale, from 1844 till 1851, and other opportunities since, he would add a word or two on the subject. With regard to heavy tie-rods, he had proved all the links of the Kieff Bridge; these links were 10 inches by 1 inch in section, and extended considerably in the 12 feet 6 inches length between the eyes. It was also found that the softer description of iron—something like cable iron—was not well suited for the purpose, as the links stretched too much, and therefore a rather harder description of iron was selected, having a higher elastic limit. The "extensometer," noticed by the Author, was used throughout, and $\frac{1}{10,000}$ inch could easily be read, and the first set of the metal determined, which was undoubtedly lower than had before been suspected. One particularly uniform bar, 5 inches by 1 inch, stretched $3\frac{3}{16}$ inches in 7 feet 6 inches, and, of course, became divested of the black scale throughout the length. He designed a proving machine, having two hydraulic presses at one end acting on a cross-head, and provided with lever arrangements at the other end to measure the strain; but a plunger, with lever and weights on the hydraulic pipe, yielded such exact results, that it was generally used instead of the lever. He thought the excellent plan of automatic registration of results, introduced by the Author, would prove most valuable, and he had no doubt it would be copied in other machines. He had tried numbers of struts for roofs and other purposes in the form of T and L irons, "channel iron," tubes, &c., by end pressure, and it was curious to notice how a strut, that at

first bent into a slightly S curve, would suddenly start into a C curve, and would then, of course, carry very little; and it was also instructive to observe a light cast-iron column first bend slightly sideways and then fly to pieces sideways with great force, due to the end pressure. With regard to experiments on steam-engines, he believed that steam was always damp unless superheated, and for this reason, if for no other, viz., that it rose through a mass of water, and would necessarily be as damp as air would be if that rose up through water; besides this, there was always some radiation going on from the steam-dome, steam-pipes, &c., and this tended to condense the steam. A new "steam-separator" had lately been found very useful in separating water from steam. It was the invention of Messrs. Boys and Cunynghame, and deserved to be experimented on. No doubt a surface-condenser was a most desirable apparatus to have for experiments with engines, and a surface-evaporative-condenser would also be useful as a valuable help in effecting economy of fuel, in many situations where water was expensive. And even with a common injection-condenser, experiments might with advantage be made in employing the whole force due to the vacuum in the jet, so as to make the injection-water break up as much as possible into minute drops in the midst of the steam, and thus use less water for injection, the temperature agreeing with the pressure much more closely. Mr. Cowper.

Experiments on steam-jacketing cylinders, and the "hot pot," in compound-engines were very important; and for obtaining uniform rotary force in a compound engine, it was undoubtedly of the greatest advantage to have the cranks at right-angles, and the cylinders properly proportioned, all which points could be experimented on in the laboratory with a good engine.

Alteration in clearance or steam-space at the end of the cylinder could be effected cheaply by attaching plates to the piston, or to the bottom or top, or, at some greater expense, by altering the length of stroke, by shifting the crank-pins in disks in place of cranks.

In all experiments on friction, he trusted that very heavy pressures per square inch of bearing-surface would be tried, as in practice it was very important to ascertain which were the best materials for the purpose. He thought the exact determination of elastic-limit was quite as important as breaking-weight. Take the simple case of a boiler, if the metal stretched and took a permanent set it was not the same boiler that it was to begin with, and one part might be strained and another not, for it was

Mr. Cowper. impossible in any case to make every part equally strong. If some of the plates were without holes and others with rivet-holes in them, and the rivets took a set, or the plates between the holes took a set, the boiler would leak or fail. He had, therefore, always made boilers to keep within the elastic-limit when proving to double the working-pressure. This at once pointed to one of the great advantages of steel for boilers, as the elastic-limit was much higher in steel than in iron.

Some years ago he had requested Mr. J. T. Smith, M. Inst. C.E., of Barrow, to rivet up a short length of boiler of $\frac{1}{4}$-inch mild steel plates, 4 feet in diameter by 4 feet long, and to try to burst it with water; this could not be done, as at 420 lbs. per square inch it leaked all over, the plates and rivets being so tough as to take a set, and stretch so as to cause leakage. This experiment was particularly satisfactory to him, as about this time, the faith of some people in steel was rather shaken, in consequence of some important boilers giving way before use. He wished British manufacturers were more enterprising in trying practical experiments, for on them depended greatly the improvement of manufactures, and the maintenance of their position, as the most advanced manufacturers in the world.

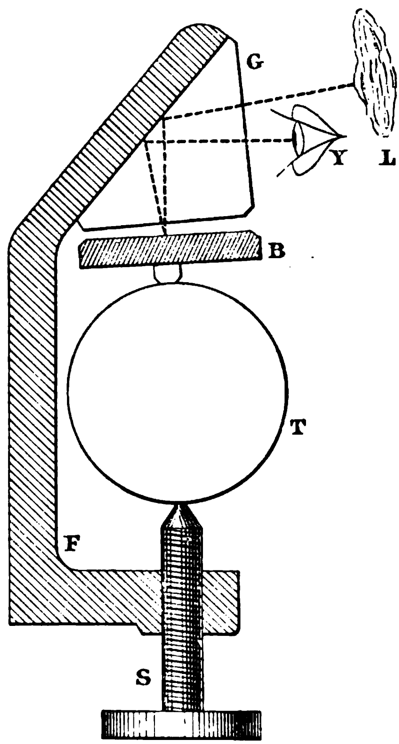
Mr. Stroudley. Mr. W. STROUDLEY agreed as to the great advantage of giving a student engineer a course of work like that described in the Paper, before entering a workshop, where, although the opportunities were greater, the pressure of work did not allow sufficient time for a close investigation of special objects. He had observed that pupils who had had the benefit of that class of training at Cooper's Hill and similar institutions, took more readily to the difficulties met with in a railway workshop than those who had had no such advantage. There must, however, be always wanting in an establishment such as that described in the Paper, the results of wear and tear. The testing to destruction would not determine the best form of a piece of machinery; and it was by observing the breakages and failures that an engineer could decide what was the most fitting for each particular purpose. He had observed a flaw or a crack in a piece of a locomotive, and had noticed from week to week, and from day to day its extension. Iron or any other metal would certainly break by a varying load, although it might be much below the observed limit of elasticity. It was, therefore, in his opinion, of the first importance for a student to learn to be exact in his measurements; and the delicate instruments described in the Paper would no doubt tend very much to exactness, and thus enable students to avoid the mistakes

that were frequently made in the designing of machinery. He had exhibited two specimens of parts of a locomotive that had broken in the way he had mentioned, and they showed that, although the iron was originally, and was still apparently, very ductile and tough, the flaw would commence and gradually extend down to two-thirds or more of the total area, yet it would not break, proving that there was more than sufficient strength to do actual work, while there was not sufficient to prevent extension beyond the limit of elasticity of the metal. The specimens referred to were cotters of an old-fashioned locomotive with forked connecting-rods. A careful estimate of the reciprocations made by these connecting-rods during the life of the cotters amounted to 50,000,000, the maximum strain by the pressure of the steam being about 13 tons. He had no doubt that very refined measurements, such as described by the Author, would have shown that these cotters had been strained to a certain degree, and although not sufficient to create any visible change of form, it was sufficient to gradually rupture the material. Mr. Stroudley.

Mr. C. E. Stromeyer said that as some of his inventions had been referred to in the Paper, and as these were, he hoped, of interest to the members of the Institution, he would give a brief explanation of one of them. The instrument, of which the main features were shown in Fig. 33, was intended to measure the cross deformation of test-pieces subjected to stresses below the elastic limit, and which rarely exceeded $\frac{1}{4,000}$ inch per inch diameter. Except to those who were thoroughly conversant with the undulatory theory of light, it would be rather difficult to explain the phenomenon on which the principle of the instrument was based. In physics it was called the interference of light, and it was more generally known by the name of Newton's rings; it could easily be produced by pressing together two small pieces of glass, say 1 inch square, and holding them behind the flame of a spirit lamp or Bunsen burner tinged yellow by salt or other soda salts. If the pieces were cut from ordinary window-glass, irregular black and yellow bands would become distinctly visible to the naked eye, and it would be noticed that by altering the pressure on the glasses these bands changed their shape and relative position. This could be thus explained:—Though there was nothing by which one band could be distinguished from its neighbour, every one coincided with the curves of equal distance between the glasses, just as fathom lines on nautical charts followed the lines of equal depths. Were these fathom lines to be redrawn, as the tide rose foot by foot, they would appear to Mr. Stromeyer.

Mr. Stromeyer. move similarly to the black bands visible on the glasses. In fact, the only differences between the two markings were, that every time when one line had moved so far as to take up the original position of its neighbour, it was a sign in one case that the water-level had risen 1 fathom, while the same motion of a black band signified that the upper glass had moved $\frac{1}{86,250}$ inch away from the other one. Fig. 33 showed a piece of black glass

FIG. 33.



B, and above it a transparent glass prism G. The light from the flame L entered the prism and was reflected from the slanting back to the lower surfaces; here the black and yellow lines were produced and the light re-entered the eye as shown. If the diameter of the test-piece, T, diminished while it was being stretched, the black glass moved away from the transparent one, and the bands moved in the direction from right to left, while if the section expanded they moved in the direction to the right

again. A motion of the bands from black to black represented $\frac{1}{86.250}$ inch, so that, by counting them as they moved backwards and forwards and comparing them with the stress applied to the test-piece, the amount of contraction might be measured. Originally the instrument had been designed for measuring local strains in boilers and ships. It was so sensitive that they could be measured on small spans of about ½ inch or 1 inch; but there was a difficulty in having to carry about a spirit-lamp, and the measurements being so very fine, were easily affected by the spring in the instrument, and he was not able to depend on the absolute value of the readings. He hoped some day to be able to perfect the instrument and to investigate the question of local straining. He had made a few experiments on this subject on boilers and ships, and had found that close to the side of the longitudinal lap-joint, in the shell of a boiler, the strains were four times greater than the calculations would show; that meant that the lap-joint was more elastic than a plate, and that all the strain was thrown on the solid plates. As far as he had observed in experiments on boilers, which had burst under hydraulic pressure, the crack extended through the seam into the solid plate; but he was not sure whether the crack did not first start in the solid plate and not in the seam. He had found by measuring the circumferential strains in a long boiler—a cylindrical tube 4 feet in diameter and 10 or 12 feet long—that the strain increased from the ends towards the centre. It came to about one-seventh of the estimated strain close to the ends where the shell was stiffened by the flat plates; in the centre of the boiler it was six-sevenths. He supposed that the reason why it did not come up to the estimated strains was the number of circumferential seams which gave additional strength to it. The instrument on the table had hardly been tried; it had been designed so that there should be little spring in it, and that its amount could be measured. From a few preliminary measurements which had been made he felt satisfied with the result, and hoped one day to be able to perfect the other as well. He also exhibited two other instruments, both of which had been described at a meeting of the Institution of Naval Architects.[1] One of them was simply an instrument for measuring the elongation of test-pieces. It consisted of two flat plates, between which a very small rolling-pin of fine wire was placed, and to which a pointer was attached. The mode of fixing this gear to the test-piece was very simple. By putting a strain

Mr. Stromeyer.

[1] Transactions of the Institution of Naval Architects. Vol. xxvii. (1886), p. 32.

Mr. Stromeyer. on the test-piece, the plates slid one over the other, causing the rolling-pin to roll and the pointers to revolve. The other instrument was based on the same principle. Two thin plates of iron were clamped to a beam; between the plates was a rolling-pin and a pointer. He had protected it by a glass plate to guard against wind. In order to do away with a long connecting-bar, which would otherwise be necessary to transmit the slight motion from the other end of the beam to the rolling-pin, he had stretched a wire by means of a spring. The only inconvenience of this arrangement was that a slight correction had to be made to the readings. He then showed that by pressing on the centre of the beam the pointer moved through an angle of 45°, proving that the top fibres had slightly contracted. He had experimented with the instrument a good deal on ships, and also on one or two bridges, and the results had been perfectly satisfactory. The rolling-pins were about $\frac{1}{200}$ inch in diameter; but by using a thicker one, and attaching a pencil to it, he had obtained the diagrams recorded in the Transactions of the Institution of Naval Architects. There would be found (Plate VII.) diagrams of three trains passing over the Hamburg bridge. The instrument was fixed to the lower limb of the big girders of the bridge, and it was shown plainly that as the locomotive came on to the bridge the strain was highest, and when the uniform load was distributed over the bridge it was less than when the tail-end of the train was moving off. That was in accordance with the theoretical views on the subject. When experimenting with the strain-indicator, he had discovered that unless it was fixed to both sides of any beam which was being measured, a good result would not be obtained. Even in the case of a test-piece, when the first pull came on it one pointer sometimes moved back and the other forward. That showed that there was a slight bend in the test-piece, or that the centre of stress did not exactly pass through the centre line. In bridge-work—in fact in all large constructions—he believed that the centre of stress did not always pass through the centre of the plate, and the consequent local buckling caused errors in the readings of the instrument if only one was attached. On that account it was always necessary to fix two instruments, one on each side of the plate, or else to have two on one side of the plate, so that by taking the differences of the two, the mean stress in the centre of the plate could be ascertained. This was a little more complicated than having an instrument on each side, but it was as easy to work it out in that way as in the other. While experimenting on

one bridge in which he thought he could compare the estimated stress with his experiments, he found that they did not agree at all as to the mean stresses; but by taking the centres of effort for three sections, and by drawing a curve through these three centres, he was able to say that the ordinary theories of the distribution of strains were correct, at least as far as that point went. Mr. Stromeyer.

Mr. EWING MATHESON remarked that the Paper and the discussion that had arisen upon it were useful not only to those who wished to make experiments in laboratories, but also to manufacturers who found it more and more necessary to have testing apparatus in their own factories. Of course it was not possible nor desirable that manufacturers should attempt to emulate the very elaborate kinds of apparatus that were to be found in laboratories; but it was important for them, as their work was going on and as material was being received into the factory, to be able to ascertain something about it, although they might not be able to do it so completely as by the processes adopted in such laboratories as Professor Kennedy's. In steelworks the tests which were so thoroughly made were to a large extent chemical tests, while in laboratories like that at University College they were chiefly mechanical. With steel, perhaps more than with iron, some of the results were very difficult to account for. Sometimes even pieces of steel that had come out of the same converter were different, and it was said that the differences were possibly due to incomplete mixing in the converter, or to some variation in the constituents, not possibly in the carbon or the phosphorus, which were of primary importance, but in the silicon, or the sulphur, or other parts that entered into the composition of steel. He thought that if the two tests could be combined; if every time a piece of steel in the laboratory were broken, or at any rate when the fracture showed something out of the common, or that could not be accounted for, the piece were sent into the chemical laboratory to be tested, and if the results were given in a parallel column on the same sheet with the mechanical tests, certain coincidences would soon be discovered; an excess of strength or elasticity, or too little of it would be associated with certain chemical conditions. The information so obtained would be of great use to engineers and to steel makers. In that respect it appeared to him that many tests were wasted, serving only their immediate purpose of ascertaining quality, but not showing the reason for the results obtained. Mr. Matheson.

Mr. G. R. BODMER did not agree with Professor Smith with Mr. Bodmer.

Mr. Bodmer. regard to the futility for practical purposes of testing pieces to rupture. It should be remembered that there were other questions of importance to practical men besides the mere strength of material. Although the elastic-limit should be the criterion in making calculations, still the total extension and the ultimate breaking-stress gave information as to other qualities of the material which were quite as important for manufacturers as the absolute strength. That was especially the case with materials subject to sudden applications of load or of impact. He thought, therefore, that, in addition to the determination of the elastic-limit, it was always desirable for practical purposes that the total extension and ultimate stress should be determined. With regard to testing materials, he thought that scarcely enough attention was paid to transverse tests. A good deal had been said about tensile tests, but, as far as his experience went, in nine-tenths of the cases in which calculations had to be made with regard to parts of machinery, those parts were subject to bending strains, and he believed that for practical men transverse tests were of equal importance with tensile tests. They had also another advantage, that although they did not give exactly the same class of information, and could not in any way supersede tensile tests, yet it was much more easy to observe the extensions up to the limit of elasticity; because where, in the case of tensile tests, the extension was measured, say, by thousandths of an inch, in the case of a bending test it was measured by thirty seconds. With regard to tests of gas-engines, the Author had remarked that the greatest difficulty was the measurement of the temperature of explosion. Of course that was true with regard to direct measurement; but he thought it was possible to ascertain the temperature indirectly with sufficient accuracy for all practical purposes. To show what he meant, he had prepared two diagrams (Figs. 34 and 35), and he might be permitted to refer to experiments that were made some time ago by Dr. Slaby, the results of which he thought justified the calculation of the temperature of the explosion on the assumption that the expanding gases followed the laws of permanent gases. Of course everything depended on that. If the products of combustion, and the other gases expanding in the gas-engine, followed the well-known law of permanent gases, there was no difficulty in calculating the temperature from the pressure, and he considered that the results obtained by Dr. Slaby afforded pretty good evidence that they did. Dr. Slaby measured directly the quantity of heat absorbed by the cooling water, and he calculated the temperature of the explosion on the assump-

tion that the gases in the gas-engine behaved as permanent gases, making a small allowance, which was known, for the slight altera- Mr. Bodmer.

FIG. 34.

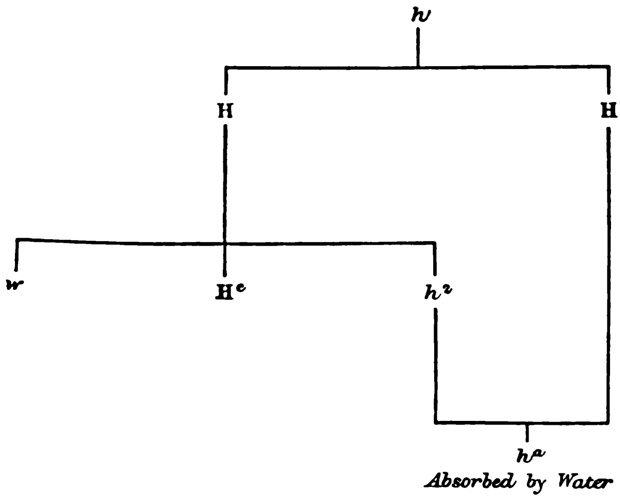
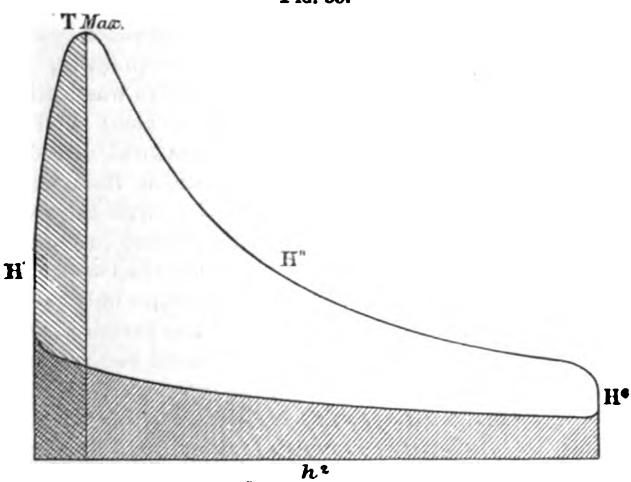


FIG. 35.



$H'' - h - H - h^a - h^2$

tion in the density of the gas after the explosion, compared with its density before the explosion. Fig. 34 showed the way in which the heat was utilized. *h* was the total heat of combustion, which

Mr. Bodmer. might be divided into two parts, first, the heat H′ developed during the explosion proper previous to expansion, and, secondly the heat H″ developed by subsequent combustion after the explosion proper had taken place. He had marked all those quantities that were actually observed, or measured directly, in italic letters, and those that were only calculated in capitals. It would be seen that the heat developed during explosion was spent in three ways: one portion was converted into work, *w*; another portion H^e was expelled with the exhaust; and a third portion h^2, in the particular case under consideration, was rejected during compression, and absorbed by the cooling water. In the case of that engine the expansion curve was found to be adiabatic, and the compression curve isothermal (Fig. 35). The fact of the curve being adiabatic could only be explained on the assumption, that while heat was being given up to the cooling water, an equal quantity was being communicated by the combustion going on during expansion. Therefore, if the assumptions on which the calculations were based were correct, the heat developed during expansion should be exactly equal to the difference between the total heat of combustion and the heat developed during explosion, and that was a point on which there was direct confirmation in the actual measurements made. It would be seen that the heat h^c absorbed by the cooling water was equal to the sum of the heat H″ given off during the expansion and the heat h^2 rejected during compression. The heat rejected during compression was a measured quantity, because, as it happened in that particular case, the curve was isothermal; therefore, the heat rejected was exactly equivalent to the work expended in compression, which could be measured directly from the diagram. Hence there were two equations, from which H″ the heat developed by subsequent combustion after the explosion proper could be calculated. In one case there were two quantities, h^c and h^2, which were both measured; in the other two quantities, *h* and H, one of which was measured and the other only calculated. That afforded a check on the accuracy of the premises, and as a matter of fact it was found that the agreement was within about 1 per cent. of the total quantity of heat developed. He thought that the study of these results, which were quoted very fully in the lecture by Professor Fleeming Jenkin,[1] in February 1884, would show that there was a sufficiently close agreement between the theoretical and the actual results, to confirm the assumption

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[1] Lectures on "Heat in its Mechanical Applications." Session 1883–84. "Gas- and Caloric-Engines."

that the gases in the gas-engine behaved as permanent gases with enough accuracy for all practical purposes, and that the engine formed, so to speak, its own thermometer. Mr. Bodmer.

Mr. C. E. Cowper only wished that twenty years ago students had had the chances and opportunities now presented to them. He had been particularly struck with the diagrams showing the curve of stress and strain (Fig. 11). The Author had very successfully made an instrument, by means of which a sample in a testing-machine could draw a curve, and graphically tell its own story. It was very important to give the student a diagram to impress facts upon his memory; he called a diagram a pictorial representation of a fact. A steam-engine was always expected to tell its own character by drawing its own diagram, and the Author had made the samples which he was testing do the same thing. But there was another way of obtaining this, namely, by construction. He had hung upon the wall a diagram, as an illustration of what he meant. This was a diagram of boiler-trials which had been exhibited on the occasion of Mr. E. A. Cowper's lecture on the steam-engine.[1] It was not drawn by the boiler itself, but it was constructed by plotting curves from the table of results obtained from the experiments with the boiler, extending over many weeks. The curve showed the varying proportions of evaporation, heating surface, grate surface, consumption of coal, temperature of escaping gases, and economy. From a study of that diagram it was easy to ascertain what were the limits within which reasonable economy could be obtained. Another reason that he had for the exhibition of the diagram was to suggest to the Author this means of illustrating the experiments with boilers which he had mentioned in his Paper. Mr. Cowper.

Mr. W. Anderson thought that the importance of engineering laboratories had not been over-estimated. That such was the case had been shown by the springing up, spontaneously, all over the country, of those admirably equipped laboratories in which students of the present generation had such enormous advantages over those who studied engineering in former years. He drew a broad distinction between the laboratory and the engineering workshop. The engineering workshop, as it was ordinarily conducted was, he thought, of very little use. The time spent in making toy engines, foot lathes, and cabinets for curiosities was time entirely wasted. It was impossible in an engineering work- Mr. Anderson.

[1] Lectures on "Heat in its Mechanical Applications." Session 1883–84. "The Steam-Engine," Plate I. Fig. 1.

Mr. Anderson. shop to make a student into a good mechanic. All that could be done was to give him a certain amount of acquaintance with the materials he had to deal with. The education, therefore, ought to be confined to teaching the student how to work with pieces of metals of considerable size, turning, drilling, planing, forging, and the like, and then doing a certain amount of fitting, to enable him to find out by experience what were the properties of the materials. He should also make the principal joints used in carpentry on the large scale, and learn the principles of pattern-making. But in the laboratory, the student had to determine practically the method of ascertaining the constants which he would be obliged to use when he came to practise his profession. The great advantage of determining the constants for himself was that he would be able to gauge their true value, and know within what limits they could be trusted, which he could not well do without that kind of instruction. It was a misfortune, which was perhaps inseparable from engineering laboratories, that they were necessarily confined to apparatus of a small class, and that they could not be very varied. He thought the discussion had shown that in most laboratories attention had been concentrated upon the testing of specimens of iron and steel, chiefly by tension, and experiments on steam-engines, mostly of a very small size; the attention and energy of the professor had been concentrated on these subjects, and consequently some very remarkable results had been produced. It had occurred to him that, in these days of co-operation, something might be done by federating engineering schools. While each of them would have apparatus for carrying out experiments on a small scale in every department, some would devote themselves to particular lines of experiment. For example: in a great shipping centre, like Liverpool or Glasgow, there would be large apparatus for making experiments with floating bodies, and their resistance in passing through fluids. In a place like Manchester there would be a good steam-engine arranged to work under all kinds of pressures and other varying conditions. In a place like Birmingham attention would be chiefly concentrated upon experiments as to the flow of fluids through pipes. Each school would come to an understanding with other schools, and devote itself to some particular line, and then, by means of federation, the students of one school might have the privilege of being transferred to another for particular classes of experiments. If that were done the value of laboratories would be enormously enhanced, the area of research would be enlarged, experiments would be made upon a greatly more extended scale, and would give the whole movement that practical

stamp which had always characterized the engineering of this country. Mr. Anderson.

Mr. H. S. H. Cunynghame said that the opening pages of the Paper had had a great deal of interest for him, as he had been employed during the last two years in making inquiries for the Charity Commission in the various modes of education, particularly technical education, which had so much to do with the training of engineers. He had visited most of the great midland towns in England, and he believed he had also visited every technical school in Paris, and the result of his inquiries amounted to this:—There were three classes of boys or young men to be considered. There was the ordinary poor lad who would never be anything but a labourer, a workman, or artisan. Then there was the poor boy, with exceptional abilities, to whom such charities as those which the Charity Commission administered might be of great benefit in enabling him to get a better education; and then there was the son of the rich man, who could afford to give him the best practical education whatever it might be. As to the first of those classes, it was impossible for the parents to support the boys while they were at the technical schools. The authorities in Paris were positively paying out of the rates nearly £74 per head for those boys in some of the schools, where they were fed and clothed as well as taught. Whether that was wise or not, he would not say, but he doubted it extremely. With regard to the richer boys the question of expense of course did not arise. As to the question of the best mode of making an engineer, he would only say that the word engineer meant one of two things. It might mean a professor who had all his life to study the theoretical part of the subject, and whose help was invaluable; or it might mean a man who had to deal with the practical affairs of life, and who wanted the moral courage necessary, in case of an accident happening, or a machine going wrong, to show that he could remedy it somehow. An ordinary engineer, who had to deal with practical matters, could not be trained except in the workshop; but it might be extremely useful to give him a year or two in a school like Professor Kennedy's, in order to teach him that there were such things as science and law; and that there those delicate experiments really had a direct bearing, if only they were properly understood and allowed for, in practice. While, therefore, deprecating any attempt to make technical schools take the place of the workshop, they might, if used wisely, and to a limited extent, be rendered exceedingly useful; and every one interested in engineering should hail their introduction with joy. They were thoroughly worthy of support Mr. Cunynghame.

Mr. Cunynghame. if once their function were understood. In France, unfortunately, they had, he thought been pushed a great deal too far. There was the École Polytechnique, and the École Centrale. Most of the young men in Paris had a great idea of going to the École Centrale, where they were kept at theoretical work until they were twenty-five, and where they had given to them "baccalauréat" for engineering, and all sorts of high titles. He had recently spoken to one of the best tool-makers in Paris, Mr. Gerard, who had an interesting school with nearly two hundred apprentices, costing the State nothing, but paying their own way and doing excellent work. Mr. Gerard said:—"I have two sons; I am going to retire, and they must take my place. They want to go to the École Centrale. If they persist in this desire I shall send them off to England, where you people are rather more practical than we are in France. I shall bind them apprentices to some firm of engineers, and they shall have no École Centrale at all. I am a practical man and do not want it." In France the whole business was pushed a great deal too far; but there was possibly a danger of Englishmen underrating such institutions, which, he thought, when properly used in connection with engineering apprenticeship, might be of the greatest value.

Mr. Pearsall. Mr. H. D. Pearsall thought that, before other experiments were made on the discharge of water through orifices, it was extremely important that preliminary experiments should be carried out as to the form of orifice most useful for gauging. It was clear from the experiments of Mr. Mair, that an orifice in a comparatively thin brass plate was an imperfect gauge; for a slight injury, which could not be detected without taking off the plate for examination, was said to have increased the flow 2 per cent., and an imperfection which could not be detected at all caused a palpable error of 1 per cent. That was very far from the ideal orifice for gauging. He hoped that some of the professors who were provided with instruments, and had time and money for making investigation, would before long contrive something more nearly approaching a perfect gauge. He might be permitted to allude to some of the very extensive experiments of Mr. Hamilton Smith which had been recently published, showing varying and anomalous results with orifices which approached much more nearly to the theoretical "orifice in a thin plate" than those used in any experiments hitherto conducted. Those results, he thought, proved that it was not true that an "orifice in a thin plate" would be an altogether suitable gauge, even if it were possible to make it. It was not, therefore, worth while any longer to aim at

that form, especially as it was impossible to get very near to it in any practical work. Mr. Pearsall.

Professor Kennedy.

Professor KENNEDY, in reply, said he desired to thank the members of the Institution for the kind manner in which they had spoken of his Paper. He was also gratified with the general consensus of opinion that some practical instruction of the kind he had endeavoured to describe was of use as a part of engineering training. Mr. Wicksteed had asked a question about the use of a couple of valves for rendering uniform the flow of water from a loaded accumulator. The valves were not put for the special purpose of regulation, but he had found the double regulation very convenient for allowing small quantities of water to pass. With regard to Mr. Wicksteed's contention that it was surely better, by taking, say, a 100-inch specimen, to multiply the length itself, than to multiply by mechanical gearing the readings taken from a short specimen, he thought that the difficulties of arranging an accurate apparatus to read the extensions of a very long bar would probably be more troublesome than the use of a more accurate and smaller apparatus. Then it should be remembered that, although the colleges had been spoken of as rich, they were in reality poor, and the preparation of test-pieces 100 inches long would be a somewhat serious matter. With regard to the statement as to an error of ½ lb. per ton (p. 16), he had perhaps not made the matter quite clear. He did not mean that ½ lb. per ton was an error due to inertia or anything of that kind; the ½ lb. per ton happened to be only an error of leverages in a particular machine, which might be anything. Lastly, Mr. Wicksteed rather differed from him as to one important practical point, namely, whether it was better to have a constant weight for all test-pieces, which weight should be run along the lever for varying distances according to the different size of the test-piece; or whether it was better to have varying weights which would run along the lever approximately the same distance for all test-pieces. It was no doubt a matter on which a great deal could be said on both sides, and it was a matter depending on practical use; but he was inclined to think that in testing a small piece with a large machine of the Wicksteed type, where the weight would only move a very small distance, the total probable error was greater than it would be with a smaller weight running a longer distance. He admitted, of course, that there were chances of error in using ten weights instead of one weight—errors in the weights themselves, but those errors should be put right. Professor Unwin had asked him a question as to the number of men who, in his opinion, could work

Professor Kennedy. in a laboratory of the kind described in the Paper. As a matter of fact he had never employed more than twenty young men at one time in the laboratory, and he did not think that practically he could do so with the apparatus he had described; but with a reasonable increase of smaller apparatus there was plenty of space for at least double that number of men working at the same time. As to the measurement of extensions or strains of one kind or another on both sides of the test-piece, no doubt that was a most important point, and it was one which he had not lost sight of (p. 35). He thought it was unquestionably much better to do it by such an apparatus as Professor Unwin had shown, in which the mean of the extensions on the two sides could be automatically read off from the apparatus, than to do it by any other method. Professor Kennedy's lever apparatus (Fig. 10) did not do that. The method he had employed with it was to use one set of gear on each side of the test-piece, which was perhaps a clumsy and troublesome way. Two men were employed in reading, one on each side, where special accuracy was required, and then the means of the extensions or compressions on the two sides were calculated. Of course it would be much better if the instrument would show it at once, as was done by Professor Unwin's instruments, and by both forms of his own diagramming gear. If, before he had written his Paper, he had seen some of the diagrams obtained from Professor Unwin's semi-automatic elastic diagramming apparatus, he should have spoken more strongly about them. They were about the most beautiful things that had been accomplished in connection with elastic measurements of any kind. With reference to some remarks of Professor Smith, he agreed with Mr. Bodmer that it would be inexpedient to throw away all knowledge of breaking-stress. It was quite certain that other things should be known; but, in saying that he could not see any practical utility whatever in finding breaking-loads, he considered Professor Smith erred in the opposite extreme. The engineer ought to know a good deal about breaking-loads. They ought not to be worshipped as if there were some kind of fetish in connection with 20 tons per square inch, but it should be known that the 20 tons per square inch at least existed. If no importance were to be attached to anything beyond the elastic limit, then iron must be considered equally good or better when pulled across than when pulled along the fibre. He hoped, however, that the whole tendency of his Paper would sufficiently show that in saying this he, at least, did not underrate the importance of elastic experiments. He did not wish it to be thought that he had neglected the point as to original work of students raised by Professor Barr. There had been already printed

Professor Kennedy.

in the records of the Institution two Papers,[1] written for the Students' Meetings by his own students on their work in the laboratory, and two or three other Papers were in course of preparation. With reference to Professor James Thomson's brake, alluded to by Professor Barr—which was a most beautiful piece of apparatus—his attention had been drawn to the fact that perhaps the first constant-resistance brake of that kind was the brake described by the late Mr. W. Froude, M. Inst. C.E., in a Paper read before the Institution of Mechanical Engineers in 1858,[2] and ascribed by him to Mr. Imray—a brake in which the arc of contact of the strap was automatically changed. He had never seen the brake at work, but it was stamped with Mr. Froude's approval, and it had every appearance of being a successful instrument. He entirely disagreed with the remarks of Mr. McGregor, whose practical mind, he thought, would, if he really understood the working of the laboratory system, lead him to a different conclusion about it. Mr. Stroudley had alluded to the importance of experiments on the growth of flaws, and the effect of wear and fatigue generally—a point of great practical importance. In some of the German laboratories, experiments on the effects of continually-repeated loads were being made in certain machines, something of the type used by Wöhler in his original experiments on the fatigue of metals. Mr. Stromeyer's apparatus for measuring the cross-contraction of a test-piece was of high scientific interest. He had himself used it lately in sundry experiments, and had found that practically all the original difficulties connected with its use had been removed. It appeared capable of giving results connected with the theory of elasticity which were of considerable importance. Mr. Ewing Matheson had not overrated the importance of combining chemical and mechanical tests. The difficulty was essentially one of time and money; but he hoped that some progress might presently be made in this direction. Microscopical investigations might also be mentioned as being of very great value along with chemical and mechanical tests. In speaking of the difficulties of measuring temperature in gas-engines, he, of course, did not at all overlook the fact that all the temperatures could be calculated. In connection with some gas-engine tests that he had recently made, in which neither the expansion- nor the compression-curves were either adiabatic or isothermal, he still had found that he was able to make the final "heat account" balance very closely. But the

[1] Minutes of Proceedings Inst. C.E. vol. lxxiv. p. 258, and vol. lxxxv. p. 376.
[2] Proceedings. 1858. p. 100.

Professor Kennedy. final corroboration due to direct measurement was very much wanted. He had found, in his own practice, that it was a great convenience to have an engine-trial, or anything of that kind, actually diagrammed while it was going on. It enabled everything that was happening during the whole of the trial to be seen thoroughly. Mr. Anderson had suggested a magnificent project for the Jubilee—a confederation of engineering laboratories throughout the country! He should be very glad if something of the kind could be practically carried out. In speaking so much of tension-tests in his Paper, he had perhaps laid more stress upon them than they received in his actual work. He had mentioned (p. 5) that tests were practically carried on in all kinds of stress. With reference to one word used by Mr. Cunynghame, and also by the President, he had a little fault to find. A distinction had been drawn between professorial and practical men; against this he desired to protest. He hoped it was not necessary to assume that because a man who was an engineer became also a professor, he then and there ceased to be practical. He had hoped that Professor Perry would have said something about his laboratory at Finsbury, which differed in some important respects from that described in the Paper. Professor Perry had to deal with a somewhat different class and age of student, and to deal with him in a somewhat different way. He did so, as far as laboratory work was concerned, by experiments which began by being perhaps pure mechanics, and ended by being nearly altogether engineering, and he should have been glad to hear Professor Perry's own description of his mode of work. In reference to Professor Smith's remarks about calibration (p. 100), he had to say that by using a reversible bell-crank lever with nearly equal arms, any errors in the lengths of the arms could be eliminated without measuring them. He had once or twice pointed out before the Institution that a good deal of practical value could be got from a knowledge of the work done on a piece of material while being tested. Of course the value of this work in inch-tons could be got from any form of automatic diagram, but automatic diagramming was very often practically out of reach. He had pointed out[1] that if the elastic limit, the

[1] Minutes of Proceedings Inst. C.E. vol. lxix. p. 30; and vol. lxxvi. p. 115. The formula referred to is $w\,x\left(\frac{r+2}{3}\right)$, where w is the maximum stress in tons per square inch, x the proportional extension, and r the ratio of limit to break. Used in this form the result is inch-tons per cubic inch of material—a convenient standard.

breaking-load, and the final extension were known, by combining those together in a particular way a very close approximation to the work done in breaking the piece could be arrived at. He had tested the formula frequently, and found that it gave a value within 2 or 3 per cent. of the diagram, which was sufficiently near for many practical purposes. He was now in the habit of putting that value upon all test reports which he sent out, and he thought that the comparison of such values after a time would be extremely interesting. Occasionally very ductile materials, which were also very strong, gave a work up to 8 or 9 inch-tons per cubic inch of material. More commonly good material gave 4 to $5\frac{1}{2}$ inch-tons per cubic inch, and poorer material 2 or 3 inch-tons per cubic inch. The measurement of work in that fashion, if it could be easily and practically done, gave what the Germans called a value-number; this combined very usefully most of the points which engineers looked at practically in valuing materials. Professor Kennedy.

Mr. Woods, President, said he must apologize to the Author and the other professors who had favoured the Meeting with their observations. By a slip of the tongue he had apparently distinguished between professors and practical men. No one was more willing than himself to acknowledge that the professors, who had been inaugurating valuable engineering laboratories, were in every sense practical men. He had simply suggested that the learned professors having stated their opinions, the practical men—by which he merely meant those who were engaged in the actual construction of machinery, bridge-work, and so on—should also have an opportunity of expressing their views. He thought the discussion ought not to terminate without the members recognizing the great value of the laboratories which had been instituted. Those who were engaged in engineering works were fully aware of the service which those laboratories rendered to engineers in their practice, and he was sure that they could not recognize too highly the assistance given to them from time to time by the gentlemen conducting those laboratories, to whom they were constantly obliged to appeal for information as to the strength of the materials which they had to employ in the construction of works. Mr. Woods.

Correspondence.

Mr. B. Baker expressed his entire concurrence in the Author's arguments and conclusions. He was one of the first to whom the Author communicated his desire to establish an engineering labo- Mr. Baker.

Mr. Baker. ratory at University College, and he had all along anticipated the great practical success which had followed the establishment of that laboratory. It had often come under his notice that a man, whose mathematical training and whose practical training in a workshop had been all that could be wished, had succeeded in designing a structure or machine which failed from an apparently insignificant oversight in some small detail, which would not have occurred had the designer acquired the habit, in an engineering laboratory, of looking upon every detail of his work as a possible test-piece, the strength of which must be determined by calculation and verified by experiment. A man might have fifty years' practical experience, and be deficient in qualifications which a year's work in an engineering laboratory would have endowed him with. How often an entire machine was constructed to determine a point which might really have been settled by testing some detail of the machine in an engineering laboratory! And how frequently practical men accepted the fact of a machine or structure showing no measurable deformation under load, as evidence that it was strong enough—a fallacy which no pupil of Professor Kennedy, accustomed to measure moduli of elasticity, could possibly fall into. He had seen able practical men contentedly wedging up a line of continuous girders at the piers to get them true to the eye, when an error of 1 inch in 100 feet meant an increased stress of 8 tons per square inch. A student, who had measured the re-actions of model continuous girders, would as soon have contemplated manslaughter. Dozens of failures occurred with pumping-machinery, because the experienced practical men who designed it were deficient in the one point of having an unmistakably clear realization of the consequences of momentum, fluid-friction, and other points which were impressed upon students by laboratory experiments. Where first principles were concerned, practical men were often not ashamed to indulge in the wildest speculations. The aim of the Author was to make an engineer practical from the foundation, and to stamp out that indolent habit of resting content with a speculation, when the absolute truth could be elicited by experiment. This habit was too characteristic of the last generation of engineers, and if things had greatly improved now, the good result was largely due to the establishment of engineering laboratories.

Mr. Barlow. Mr. W. H. Barlow, Past-President, said he had been much impressed with the importance of the subject on which the Paper treated, and the comprehensive manner in which the different natures of testing had been handled by the Author. Although the title of the Paper was "The Use and Equipment of Engineering

Laboratories," yet to his mind it had a much wider scope. It was not only the student who was benefited by acquiring the art of making experiments, or the art of accurate measuring in matters relating to engineering science; but, as related to materials used for structural purposes, there was the valuable amount of increased knowledge, which was obtained by the employment of the more perfect machines introduced of late years. Of course great accuracy in the recorded results lay at the root of the usefulness of any testing machine, and great care was necessary to ensure that no other action, except that which belonged to the test-piece itself, was recorded. The next consideration of importance was to secure that the whole of the varying results should be recorded; and here it was that the self-recording or automatic testing-machines were so valuable. It appeared by the Paper that Professor Thurston constructed apparatus for this purpose in 1876. But the first machine of the kind he had seen in this country was that at Cooper's Hill College, arranged for automatic registration by Professor Unwin. The third important step was the construction of testing-instruments which were portable, and capable of application to a structure after its completion. One of the earliest instruments made with this object was, he believed, contrived by the late Charles Wild. But the strain-indicator of Mr. Stromeyer was a further development in that direction. A very accurate portable automatic strain-recorder would be an extremely valuable instrument; and although Mr. Stromeyer's invention might admit of greater perfection, yet he had advanced very considerably towards obtaining such an instrument. Having regard to the training of young engineers, he thought that the general scheme of the laboratory of University College, as described in the Paper, had been very carefully studied; and that in this and in other institutions where students were enabled to make actual experiments, and see and note for themselves the behaviour of materials under different conditions of stress and strain, the knowledge so obtained by the students, and the bent or turn of mind which resulted from it, could not fail to be of great value in their future professional careers. Mr. Barlow.

Dr. H. BUNTE, of Munich, stated with regard to the station for heat experiments at Munich, that it was not used directly as a laboratory for educational purposes. He wished that, in view of the great importance which the heating question, without doubt, possessed for all industries, the study of this branch of technical science might be included in the curriculum of technical colleges, or placed upon a broader basis. At present, the ar- Dr. Bunte.

Dr. Bunte. rangements and lectures at technical colleges, both in Germany and in other countries, appeared to him to be incommensurate with the importance of the subject; and the flaws, which manifested themselves in the education of engineers in this direction, made themselves only too much felt in practice. The want of a thorough education in these matters showed itself in the patents, as numberless as they were worthless, which were not only taken out and put into practice, but were also introduced in good faith by large numbers of manufacturers. These were dearly paid for, because their worthlessness was only realized by actual use, and the manufacturers obtained experience by the damage they suffered. It was obvious that a deep-rooted prejudice was thereby created against rational improvements in heating-arrangements, and progress was delayed. On this account an extension of engineering laboratories in this direction would be highly welcome.

Professor Ewing. Professor J. A. Ewing observed that all teachers and students of engineering were under great obligation to the Author, first, and specially, for having originated that excellent institution, the College Engineering Laboratory, and now for having described and discussed its equipment in a singularly full and interesting Paper. To no one, perhaps, did that come more opportunely than to him, as he was just then engaged in arranging plans for a laboratory in a new Technical Institute, which was about to be founded in close connection with University College, Dundee. This laboratory would be in its main features similar to the Author's; and it would be worked in conjunction with the laboratory of electrotechnics which was already attached to his chair. The two together would, he believed, form a fairly comprehensive means of study in the experimental side of engineering, and their association with one another would increase the range of work possible in each. To take one part of the Paper alone, the section which dealt with the strength of materials was a mine of most valuable information on the whole subject of testing and testing machines. With regard to the Watertown machine, the Author had remarked (p. 14) on the want of any published detailed drawings. There was, however, a description of the machine in Appendix 24 to the Report of the U.S. Chief of Ordnance for 1883, written by Captain J. Pitman, which showed the construction fully by twelve plates drawn to scale: it gave, however, no information as to the methods that were used in calibrating the machine. In discussing the relative advantages of single-lever and multiple-lever testing-machines, the Author had, he thought, omitted to mention one point of some importance. All testing-machines, which employed a weight

to measure the pull on the specimen, were more or less liable to error on account of the inertia of the weight and of the connected parts of the machine. It was impossible entirely to avoid oscillation of the lever or levers; and in order to prevent these from causing important errors in the recorded stress, the inertia of the oscillating system should be minimized. In a testing-machine in which the specimen was directly loaded, without any multiplication, the inertia would be simply that of the suspended weight (M). In a lever machine multiplying the force n times, the weight required to give the same pull as before would be $\frac{M}{n}$, but its inertia, referred to the specimen, would be $\frac{M}{n} \times n^2$, or $M\,n$. Thus the inertia which was effective for producing oscillations was increased n times, apart from the additional inertia which the lever itself contributed. As an extreme case, he might instance one of the Fairbanks multiple-lever platform machines, in which the value of n was 24,000. It was not the least merit of Mr. Wicksteed's excellent machine that the effects of inertia were in great measure avoided by using a large weight and a small leverage. He had heard objection taken to Mr. Wicksteed's machine on the ground that, in testing specimens whose strength was much less than the capacity of the machine, the travel of the poise became too small to ensure accurate results. The objection might have some force in the case of specimens of very small section; but it might be obviated by having a supplementary poise, much lighter than the principal one, slung by tackle above the lever, so that it could be readily lowered on to the lever and used for light work, the main poise being meanwhile run back to the zero position or beyond it. Professor Ewing.

The name "yield-point," suggested on p. 26 for that generally well-defined point in a test at which the specimen began to "draw" notably, appeared to him an excellent one, which he was very glad to adopt. It was high time that the phrase "limit of elasticity" should cease to be applied to a point which usually, if not always, came distinctly further on in the test than the stage when Hooke's Law ceased to hold. This faulty usage had of course sprung from the fact that, in ordinary tests, the true limit of elasticity (so far as there was any true limit of elasticity) came not very far from the yield-point. Even then, however, the experiments of the Author and of others had shown clearly the necessity of preserving a distinction. And, in the cases of pieces which had been strained beforehand so as to receive set, the distinction was

Professor Ewing.

still more important. Bauschinger's results appeared to show that in such case the true limit of elasticity was separated by a long interval from the yield-point, especially if the set had been recent, and that it gradually crept up towards the yield-point with the lapse of time. In this connection he might refer to an experiment he had recently made, which served to bring out very clearly the distinction of the yield-point from the elastic limit in a strained piece. It was well known that when iron and steel were strained by a load W which gave permanent set, and the load was left on for some hours or days, then, on continuing to load, a new yield-point would be found at a load W′, considerably greater than W. In experiments with soft iron wire he had recently found that if, under these conditions, the load were increased (after remaining constant for a day or more) to a value between W and W′, and kept constant at that value, then, although no plastic extension was immediately visible, after a few minutes the wire would begin to stretch; this stretching would presently become faster, and might go on for hours until rupture occurred, or might become slower again and finally stop. Nothing could show more clearly than this, that the effect of keeping the load W on for a long time was not to elevate the elastic limit above W, but only to elevate the yield-point, and that the apparent absence of plasticity which was observed, while W, after being kept constant for a time, was being increased at any usual rate to W′, was in reality due to viscosity.

The Author had referred to the release of stress which occurs at the yield-point in the testing of ductile materials (the line A_2 B C, Fig. 11, p. 27). With regard to the question of whether it was important that this should be recorded in a stress-strain diagram, it should be noticed that, so far as the property of the material under test was concerned, this phenomenon only showed that the material was extremely plastic just after passing the yield-point, and that its plasticity made it capable of continuing to stretch under a reduced value of the load (which was true of all points in the plastic stage of the test). For the rest, the line A_2 B C depended on the mode in which the load was applied. At the yield-point A_2 (which, it might be mentioned, came early or late according as the true rate of application of the load was very slow or fast), the material began to flow so fast that the pumps did not keep pace with the demand that the hydraulic cylinder made on them: the pressure in the cylinder fell, and the stretching of the specimen went on at a reduced rate. At B the rate of stretching of the specimen was so much reduced that the pumps were supplying water fast

enough to make the pressure once more increase. By throttling the supply of water to the hydraulic cylinder, the point B could be made to fall in greatly, and the same remark applied to the final portion of the curve just before rupture occurred. These essentially arbitrary features of the diagram would be avoided, if the test was conducted so that the load increased at a uniform time-rate. Of course even then the whole plastic stage of the operation would remain arbitrary in this sense, that the relation of strain to stress in it depended on the particular time-rate employed. He thought that exception could not fairly be taken to the autographic arrangement applied by Professor Unwin and others to Mr. Wicksteed's machine, on the ground that it did not show the part A_2 B C; and that in fact it was very much to be preferred to the hydraulic apparatus employed by Mr. Wicksteed himself. Professor Ewing.

The Author had referred to tests of wires as one of the features of engineering laboratory work. In his opinion this should be made a very important feature. It was true that experiments on so small a scale did not give that knowledge of the strength of materials which was required in practical design. But, so far as the investigation of physical properties of metals was concerned, he believed that much better work was to be done with wires than with large specimens. Apart from their being easy to handle and cheap, specimens of wire had the advantage of being sufficiently homogeneous and uniform to allow differences in the condition of loading, or in other extraneous conditions, to be investigated more readily than could be done with plate-strips or bars. The variation of elasticity and strength under complex modes of stress, the effects of speed in loading and of intervals of time when loaded or unloaded after strain, the range and degree of agreement with Hooke's Law, the effect of repeated loads, the effects of vibration and magnetic disturbance on plasticity and strength, and many other matters requiring numerous specimens to be tested, as nearly as possible uniform in quality, furnished a rich field for research in which the material might most appropriately be in the form of wire. With work of this kind, he conceived that an engineering laboratory might properly take the place, to a great extent, of a physical laboratory for engineering students.

Mr. J. G. Mair observed that there were some few points in connection with testing engines on which he would like to remark. Only one type of valve-gear was suitable for an experimental engine, and that was where four separate valves were used for each cylinder, namely, two admission valves and two exhaust valves, and they Mr. Mair.

Mr. Mair. should be driven by adjustable and variable shaped cams, so that every form of indicator diagram could be produced. The position of the cross-head for equal increments of time might be readily ascertained by electricity, which would show exactly the influence of the angularity of the connecting-rod, and also the effect on the uniformity of rotation with altered fly-wheel weights. These studies would be of practical value and most useful. The engine at University College was so small, and the clearances so abnormally large, that the difference in many of the trials when made under the conditions, scheduled on p. 43, would hardly be appreciated; and although the different trials were well worth making, and were most important, it was a question if the Author was not trying to do too much with the engine he had at his disposal. In testing, it was stated that no doubt the best position for the thermometer to measure the temperature of the air-pump discharge was where the highest steady reading was obtained; but, if there was any variation of temperature between one part and another of the discharge, it was a proof that the waters were not properly mixed, and an additional length of discharge-tank should be added with baffle-plates in, so that a thorough mixture might take place. This was a point which demanded special attention. It was always advisable to work with a small quantity of injection water, so as to have a large rise of temperature between it and the air-pump discharge; this assisted in eliminating the difficulty, and in diminishing the errors due to measuring small increases of temperature. Measurements of jacket-water required some care, and the engine ought to be running under the trial-conditions at least an hour before the trial was commenced; much more water was condensed at starting, and even for some time after, than when all was hot and in good running order. The air-pump discharge was readily measured, but unfortunately a certain portion of heat passed away with the air and as vapour, so that it was almost an impossibility to get the rejected heat to exactly check the boiler-delivery; but if the measurements were carefully made, the difference, as pointed out by the Author, was not a large one, though generally sufficiently large to make any calculation of the priming-water based upon it a very doubtful one. Messrs. Hirn and Hallauer had used the rejected heat for this purpose, but on trials he had not been able to do so. The moisture in the steam was readily deposited by using one of Boys' and Cunynghame's separators, but the measurement of pure priming-water, apart from condensation in pipes, was difficult, and he should be anxious to hear the result of the salt-tests which had been largely used abroad. Independent testing

was gradually being adopted, and it was open to argument what was the best unit of measurement for engines and boilers. The Author evidently adopted lbs. of water per HP. and per lb. of fuel, reducing the results to "from and at 212°," but it surely was better to use thermal units per HP. and per lb. of fuel, as then no mistake could arise as to whether the corrections had been made, as they were not needed; and also as the steam-engine was a heat-engine the results could be more readily compared with any other form of heat-engine, and it would impress upon the students the fact that the water or steam was only the carrier or means of transporting heat from the boiler, without which the engine could not work. It was also as important with coal- and boiler-trials to give the results in thermal units. Unfortunately at present it was only usual to say, that in a boiler using a certain quality of coal, 8 or 10 lbs. of water, for instance, were evaporated per lb. of fuel; this was a valueless statement if made by itself, unless the temperature of the feed and the boiler-temperature or pressure was given, while the number of thermal units obtained per lb. of coal required no further data or qualification. In Appendix I, Form A, no notice was taken of the vacuum inside the cylinder, which was far more important for practical purposes to compare with the barometer than was the vacuum shown on a gauge. The percentage of water in the steam was noted at cut-off and release, and although no mention had been made, it was to be presumed that the transference of heat which accompanied the initial condensation was noted, and the equilibrium that existed between the interchanges of heat through the cylinder-walls was made a subject of study; for the condensation on admission was not all wasted, while the evaporation during exhaust, or, as it was sometimes called, the exhaust-waste, was entire loss of heat. Mr. Mair.

Mr. A. MARTENS observed that on many points he could agree with the Author of the Paper, although on others he had somewhat different views. These divergent views were, no doubt, chiefly due to the fact that the demands made on the machines and apparatus, in consequence of the character of the Institution under his guidance, were necessarily somewhat different from those which, from the teacher's point of view, must be insisted on. The "Königliche Mechanische Technische Versuchs-Anstalt" of Charlottenburg, Berlin, had only to serve educational purposes in a secondary degree. Mr. Martens.

The concession, permitting young technical students to enter for three months as volunteers, and learn by personal experience all the manipulations and methods of testing materials, was seldom

Mr. Martens. made use of, and demonstrative experiments were only occasionally made for the students of the Technical University. The work of the Institution consisted chiefly in the execution of commissions received from State-officials and from private individuals, and in carrying out experiments of scientific interest.

For the reasons given, in order to achieve a complete division of labour, it was his constant endeavour to bring the arrangement of the Institution nearer to such a condition that, for particular purposes, particular machines and apparatus, especially fitted for those purposes, were provided. Accordingly the Werder machine was principally employed for compression, buckling, shearing, and torsional tests; while tensional tests were carried out almost exclusively with flat bars, chains, ropes, belts, &c.; as also for all experiments which required the exertion of a greater force than 40 tons.

Tensional experiments with round bars were made by the vertical machine which he had designed; but bending tests up to 40 tons, and with distance of less than 1·2 metre (3 feet 11·25 inches) between the supports, by the Wedding machine. There were besides a number of small special machines. An automatic water-pressure engine produced a working pressure up to 300 atmospheres (4,410 lbs. per square inch) for the first two machines.

With regard to vertical and horizontal arrangements of the machines, he shared in general the views of the Author; but in view of the circumstance that knee-levers could not be avoided in horizontal machines, he preferred a single lever with a large leverage, as in the Werder machine. This arrangement had undoubtedly the advantages of simplicity and reliability, provided that the knife-edges were long enough to sustain permanently, and with safety, the great pressure (250 kilograms per millimetre, or 13,999 lbs. per inch, length of the knife-edge should not be materially exceeded), and that the knife-edges of the short arm were perfectly rigid, while that at the end of the long arm was adjustable. The adjustment of the central knife-edge, as found in some of the older Werder machines, was not so advisable; it could, as stated, be avoided. The drawback, it seemed to him, was common to all machines working horizontally, namely, that the application of a check-balance for accurately determining the leverage, necessitated the use of a knee-lever. In the case of the Werder machine in particular, its check-balance was in so far unsatisfactory, as that the check-weight to be used did not invariably have the same effect; the weights must be very accurately placed in the middle of the scale-pan, and the loads available were very small

in comparison with the work done by the machine. He could not, Mr. Martens. however, judge to what extent the same evils were present in the Greenwood and Wicksteed machines, compared by the Author with that of Werder, as he was not familiar with them from personal use. The Greenwood and Werder machines differed in principle only, in so far that, in the former, motive power and the measurement of the force were at opposite ends of the test-piece; while in the latter, both were at the same end. An advantage resulted from this, which the Greenwood machine certainly appeared to possess, that was the rigid position of the weighing-system. He believed that this advantage was not outweighed by the deficiencies which resulted from the necessity of inserting intermediate members between the source of power and the test-piece, or else shifting the source of power when it was desired to work with pieces of different size. The mobility of the weighing-system of the Werder machine forbade the use of a second lever with sliding weight, and consequently prevented the load being made continuous in its action by this arrangement; the attainment of this condition in other ways was, however, by no means excluded.

He cordially agreed with the Author in what he said (p. 14) about the publication of the results of experiments on the degree of accuracy of testing-apparatus. He considered this question to be one of the most important of all. In view of the weight and significance which the public, as he believed rightly, attached to investigations of this nature, it appeared to him to be a justifiable demand that the accuracy and reliability of the methods adopted and apparatus in use should be known, and capable of being verified. It made a bad impression when, as now, the results of tests of the strength of materials were published by scientific journals and scientific institutes, in which the breaking-load per square millimetre, as well as the total extension in percentage, was given to four places of decimals. Such a proceeding could only be caused either by boundless thoughtlessness or by a childish disregard of the actual sources of error; it brought prominently into notice, however, the necessity of attending to these sources of error in experimenting. Following the Author on this point, which had attracted attention within a large circle, he should like forcibly to express the wish, that work on the determination of the sources and limits of error should be more frequently undertaken and published than hitherto. He agreed entirely with the Author's judgment on the Watertown machine, so long as the accuracy of transmission through the hydraulic system was not proved by the publication of unimpeachable experimental results. From the publications so far

Mr. Martens. known to him, he was unable to consider them of a high degree of accuracy. With the view expressed by the Author (p. 16), that the accuracy of the lever system might be safely determined with small loads, he could not unconditionally agree. It would, at any rate, be necessary to be previously convinced that the deflections of the levers, the compression of the knife-edges and bearings, or their attachments, &c., generally not negligible with heavy loads, were of no practical importance, which, especially where bell-crank levers were used, might easily be the case. These alterations of form could generally be readily observed with levels. The control under heavy loads was in fact difficult, and, in essential points, Professor Bauschinger's method would have to be followed, of effecting this control with the help of a bar of large section strained within the elastic limit. In doing this, the elastic extension produced by a certain increment of load, say 1 ton, should have the same value for a small load as for the maximum effort of the machine. By this means the constancy of the leverage could be ascertained, not however the variation in the sensitiveness of the balance. In view of the difficulty of the problem, every suggestion would be welcome, and he therefore took the liberty of directing attention to the following points. In applying Bauschinger's method, the balance might be deflected, either by placing small weights in the pan (as done by the Author), or by a definite measured increase in the force exerted by the test-piece, the latter being effected in the Werder machine, by placing weights on the check-balance. In the former case, the first indication of a movement of the measuring instrument (mirror-apparatus) attached to the check test-piece, was observed; in the latter, an accurately-adjusted electric contact, connected with the end of the lever, showed the slight movement produced by the increase of force. By this means, with the use of very slight motions, it was possible to obtain at least an approximate measurement of the extent of the variations in the sensitiveness. He shared the opinion of the Author, that the errors of the better testing-machines for materials lay within the limits of the variation in samples taken from the same piece of material.

It was in many cases doubtless of importance, as regarded the behaviour of the test-piece, that the load should increase continuously, and not intermittently; and he was altogether inclined, under otherwise similar conditions, to give the preference to the machine with a continuous increase of load. This was, in his opinion, the chief objection to the application of the usual method of intermittent loading, for he could not recognize the advantages

which the proceeding with definite intervals in the stress was said to have in determining the limit of elasticity. With the one, as with the other method of loading, the object would always be to ascertain the differences in the elastic extension for each increment of the load, in order to obtain from it the "limit of proportionality," according to Bauschinger's definition. This point, and the "yield-point" (*Streckgrenze*) or commencement of "flow," were the particulars to be determined by accurate measurement, and which were of practical importance in forming a judgment of the material; all intermediate observations had in this connection only a very subordinate importance, and, strictly speaking, served only as an index of the reliability of the apparatus and of the observer. The proof of the proportionality was dependent only on the equality of the chosen intervals; that of the limits of proportionality and extension, on the absolute stress at a given moment. It was obviously a matter of indifference practically, whether the calculation necessary in both cases was made before or after, as long as it was intended only to determine the characteristic points mentioned. In spite of the preceding remarks, he by no means denied that the lucidity of the results was increased by use of continuously increasing stresses, but no labour was saved by it. Mr. Martens.

The remarks made by the Author (p. 19) induced him to touch upon another point. It was very advantageous, and almost always desirable, that the observer should not only have the whole of the test-piece in view, but also, as far as possible, without changing his position, overlook the entire machine and direct his assistants; or, what was better still, the machine should be so constructed that the observer could alone personally manipulate the whole apparatus, as well as watch the test-piece. Horizontal machines could generally only be arranged with difficulty, so as to be entirely under observation. The Werder machine at the Berlin Institute was connected with the water-pressure engine mentioned by him at the commencement. In the delivery-pipe there was a regulating valve, which could be operated by the observer from any point of the machine. The balance-lever was provided with an electric arrangement, which gave notice to the experimenter, by means of a bell, when the balance was in position. The assistant had, during the experiment, merely to place the weights as directed. With the new vertical machine designed by Mr. Martens, the observer was able from his post to carry out all the operations alone, including the putting on of the weights, so that he required no kind of assistance. With respect to the measuring-instruments for elastic extensions, he did not quite agree with the Author. He must confess

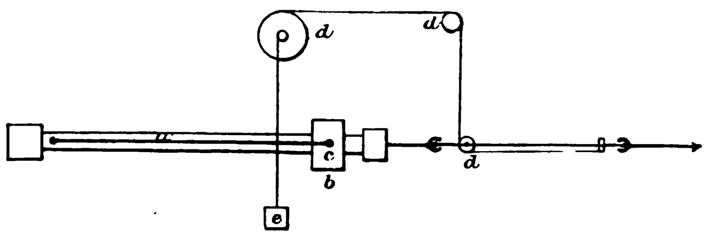
Mr. Martens. that he gave unqualified preference to the method of mirror-readings introduced by Bauschinger, on account of their certainty and convenience. He was firmly convinced that mirror-apparatus would obtain increasing recognition, the more it became the practice to determine the sources and limits of error within the range of observations.

The Werder machine determined the construction of Bauschinger's apparatus, and this had resulted in somewhat heavy forms, and long mirror-axes. These instruments might, however, be made materially lighter and handier. This had been done in the case of his new vertical machine. The mirrors were now so light that the heaviest of them weighed only 23·14 grams (0·814 oz.); they could be attached to the test-piece with a light spring-pressure, and keep their position so firmly that the adjustment to a particular point on the scale could be effected without trouble. This apparatus differed from Bauschinger's in principle, in the fact that he had used a lever-arrangement instead of the rollers. The lever was formed by a prismatic body with two knife-edges, one of which was in contact with a light mark on the test-piece, while the other fitted into a spring similar to that on the Bauschinger instruments. The dimensions were so chosen that, as with Bauschinger's apparatus, $\frac{1}{10,000}$ millimetre could be estimated.

When the apparatus was well set up, the measurements were so accurate, that on repetitions of the test, the mean differences in the extensions of the test-piece per ton increment of load (of course within the limits of proportionality) did not vary more than 0·0003 from one another. With simple removals and repetitions of the load (where the mirror apparatus was not removed in the interim and attached again) greater variations than 0·0005 with the same load rarely occurred. In opposition to the Author's statement, p. 21, "and by a somewhat uncertain estimation to one-tenth of this," he must cite the repeatedly proved fact, that even persons unaccustomed to this kind of estimation nearly always read the same number as the practised observer. This need cause no surprise, as the division appeared over 1 millimetre (0·039 inch) in size through the telescope, and the fine hair moved firmly on the scale if the apparatus was in order; every slight vibration of the balance could be detected by the motion of the hair. Mirror-readings had the indisputable advantage over micrometric measurements, in as far as he knew the latter, that they were less influenced by changes of temperature during the experiment. With microscopic readings, and with many other arrangements, it

was very difficult to prevent the measurement being influenced by the heat of the body of the observer. In addition to this there were many other errors, so that if a comparative investigation of errors were carried out, it would probably confirm the view that the errors of the mirror-instruments were at least as small as those of other measuring apparatus. On the diagram apparatus described by the Author on pp. 30 and 31, he would say a few words. The apparatus of Wicksteed was without doubt very interesting, and he was convinced that it would give good results; the fact must, however, be considered that it only measured the pressure of the water in the working cylinder of the machine, and not the force exerted on the test-piece. He had himself applied the principle of the Author's apparatus in a somewhat different form, at the Berlin Institute, without having known, however, the Author's method. His apparatus, designed in 1885, had been completed in the course of 1886. The first apparatus was connected with Mr. Martens.

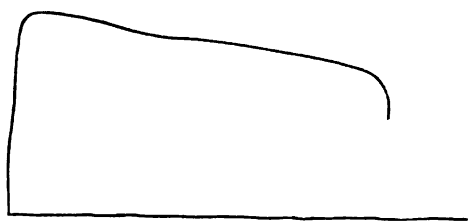
Fig. 36.



the small Rudeloff machine for 1,000 kilograms (2,204·6 lbs.) load; two others were in course of construction for the Werder machine. In his apparatus, as in the Author's, the elastic extension of a special intermediate body (Rudeloff machine), or of a part of the machine (tension rods of the Werder machine) was used as the measure of the force exerted, Fig. 36. With one end of this force-scale the rod *a* was connected by screws in such a manner that it would swivel; with the other end a small plate which carried a microscopic object-glass *b*. The other end of the rod *a* carried a finely ground diamond style *c*, which, under a very slight pressure made a mark on the glass plate. The extension of the test-piece was transmitted to the diamond-holder on a reduced scale by means of the system of rollers *d* and very fine watch-springs; the counter-weight *e* stretched the springs. The resultant diagram occupied about 1 square millimetre. It was measured by the help of a Zeiss microscope, furnished with objective and eye-piece screw micrometer. The Author effected enlargement by mechanical,

Mr. Martens. and he by optical means. In his first apparatus he used a screw transmission for reducing the ordinates for the extension, and this was the reason that the apparatus did not yet work entirely to his satisfaction. He was, however, certain that it would do all that could be required from a diagram apparatus. The main advantage of the arrangement used by the Author and himself, he considered to be by no means confined to the apparatus as such, but that it rather lay in the application of a strong spring with slight elastic alteration of form, for the intermediate force-scale was nothing else. By this means the test-piece was strained in a very favourable manner, and the diagram obtained in closer approximation to its true form. It must not be forgotten that the diagram represented by no means only two factors, namely, the force sustained by the test-piece, and the extension produced in the latter; but that the speed with which the experiment was carried out also found expression in the diagram. If by way of illustration the flow of

Fig. 37.

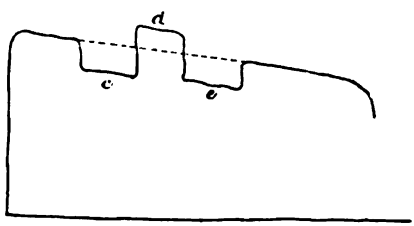


the solid body was compared with that of water, it would be found that, to produce a more rapid flow in a given channel, a greater head was necessary, in this case a greater force. In consequence of the great internal friction of solid bodies, the latter were unable to follow the motive force at an indefinite speed, and a parting, the fracture, occurred prematurely. For both reasons probably it was found that in carrying out a test rapidly, the strength was greater than when this was done slowly; for in the former case, on account of the premature rupture, the sectional area of the fracture remained larger than in the latter. With sheet zinc, for example, he had obtained diagrams with his diagram-apparatus, which usually had the form shown in Fig. 37, when the work was done with uniform velocity. If, however, during the experiment the velocity of extension was changed, the diagram had somewhat the appearance given in Fig. 38; with a low velocity the distance *c* and *e*, with high velocity *d* was traversed. It was easy to obtain differences in the force-ordinates, which

amounted to more than one-third of the maximum heights. In a similar way he was able to prove with Polmeyer's machine, that with steel a diminution of resistance of about 1·3 per cent. was effected by slow operation, under by no means exaggerated conditions. The favourable action of springs with slight alterations of form was still more clearly illustrated by the following experiment:—With his diagram-apparatus he had investigated several strips of zinc, by causing the machine to be worked with a certain velocity, but interrupting the action at certain times during the experiment. Mr. Martens.

Fig. 39 (p. 150) contained all nearer particulars and results of the measurements, which spoke for themselves. The influence of time on the extension of the metal could be here very plainly recognized; and it could be seen that a test with zinc would have to be made with extraordinary slowness if the test-piece was to be fractured with the smallest possible load.

FIG. 38.

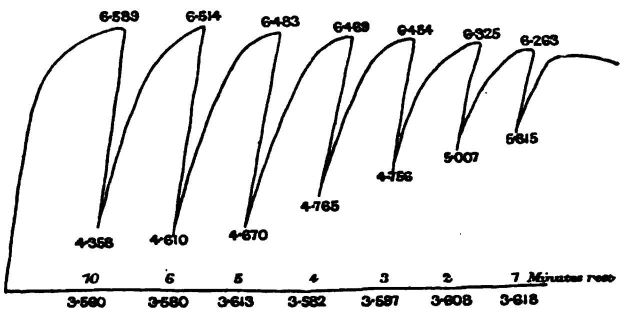


The question was then—what is the ultimate breaking-load peculiar to the test-piece? How must the piece be loaded in order to obtain a safe measure for the breaking-load? As a whole series of other phenomena on the test-piece here came in question—among others, the fact, that a tensile test was not merely a simple operation, and not one of overcoming only a single form of resistance, had prominent importance—he would here only remark, that it appeared to him indispensable to give the speed with which all experiments were carried out; with copper, zinc, and other soft metals no definite judgment could be formed without this statement. With these substances in particular, the use of a spring with little play (in his apparatus, 1,000 kilograms only caused an extension of 0·602 millimetre), had the great advantage, that a material overloading of the test-piece could not occur, such as might take place when a carriage with considerable motion and large mass was used. As soon as the bar stretched, a corresponding contraction and relief of the spring resulted. With respect to the diagrams,

Mr. Martens. Figs. 15 and 16, he might remark, that cast-iron could not be regarded as strictly elastic, if elasticity were defined as that property, in virtue of which a body after an alteration of form recurred to its original shape. Even after very slight loads permanent extensions were found, a "limit of proportionality" did not exist; on the contrary, the differences in the extension for equal increments of load increased continuously.

He shared the Author's view, that the question of the attachment of the test-pieces was one of the most important, and

Fig. 39.



All figures represented turns of the Micrometer screw; I R = 47·5 kilograms (104·719 lbs.).
From the above figures the following values resulted.

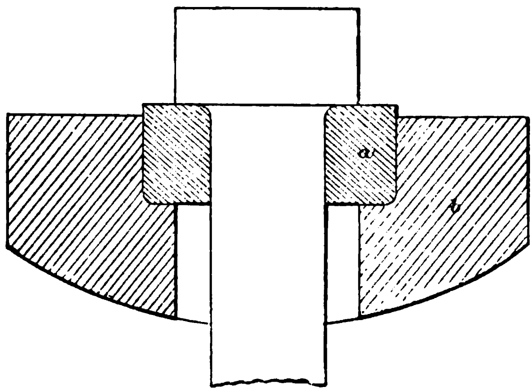
Experiment 1. Pause in minutes . . .	10	6	5	4	3	2	1
Difference between Datum line and lowest point	0·798	1·030	1·053	1·183	1·159	1·399	1·697
Or in percentages of the maximum load. 6·589 − 3·560 = 3·029 . .	26·3	34·0	34·7	39·0	38·3	46·1	56·0
Experiment 2. Differences as above . . .	0·152	0·379	0·382	0·492	0·559	0·851	1·050
Or in percentages as above. 8·875 − 6·458 = 2·417 . .	6·3	15·7	15·8	20·4	23·1	35·4	43·5
Mean of both experiments in percentages	16·3	24·9	25·2	29·7	30·6	40·8	50·0

he believed that the desired end was still to be most simply attained by spherical holders, although he was not convinced that their action could be perfect. He could not, however, approve the principle of construction shown by the Author in Fig. 17. It was quite impossible to cut the screwed heads of the actual test-piece perfectly central and equally clean; the pieces must therefore be screwed more or less askew into the nuts, and then the centre line of the test-piece no longer passed through

the centre of the spheres, so that a bending action necessarily resulted. The ball-holders, as he had constructed them for his vertical machine, were formed as shown in Fig. 40. The test-piece rested with a plane surface, which could be accurately produced on any lathe, on the two divided and hardened steel ring-pieces *a*, which were held together by the spherical body *b*. As regarded the attachment members of the machine, he inclined more and more to the opinion that the best construction was that in which all intermediate members were avoided. Mr. Martens.

If only special machines were available, then doubtless the excellence of the work and construction might be such, that the movable link connected with the balance could be so easily and

Fig. 40.



accurately guided, that lateral motions would be excluded. With the motive mechanism, this could be done without difficulty, and then by the use of ball-holders the intermediate members might be entirely avoided.

If the system of using an intermediate elastic measuring-rod, as applied by the Author and himself, was employed, a course which might perhaps be recommended for very heavy machines, in order to avoid the knife-edges, the execution of his suggestion was particularly easy. The use of the last-named system would result in very simple machines. A 300-ton machine would be constructed with three parallel rods, each of which had been accurately tested in a 100-ton machine, and each of these rods would be furnished with a diagram-apparatus. He believed the accuracy of measurement would be amply sufficient for such great loads.

In conclusion, he would draw attention to one point, not touched on by the Author. That was the method of ascertaining the total

Mr. Martens. elongation. He considered the determination of the percentage of total elongation, by measuring the distance between two centre-punch marks, to be very imperfect, because the result was then dependent on the position of the fracture relative to these points. The Munich conference, in order to meet this evil, laid down the principle, that the extension of test-pieces should be measured in centimetre divisions, so that the result referred to lengths of 10 centimetres of the original distance on each side of the fracture. At any rate it seemed necessary, that in publications and in supply-contracts, it should be stated how the elongation was to be understood.

Dr. Ryan. Dr. J. RYAN considered that too much ought not to be expected from a laboratory steam-engine. Without questioning the great educational advantage of systematic testing, it might be pointed out that no engine, however carefully and elaborately designed, could operate efficiently in a variety of ways. Nowhere had the maxim *ex uno disce omnes* been so unwarrantably applied as in steam-engine practice. Experimental results had been alleged for, and against, every known type of engine. Isherwood's carefully worked out conclusions against the use of steam with much expansion might be instanced; and it might be asserted that every particular method of utilizing the power of steam required special arrangements and proportions of parts, which were not so conducive to maximum efficiency in other methods. Moreover, laboratory engines were usually small, and hence the action of the sides of the cylinders was exaggerated, so that the results obtained could hardly be alleged as precedents for engineering practice. Dr. Ryan wished also to add his testimony to the universal merits and efficiency of the Wicksteed testing-machine.

Mr. Sells. Mr. CHARLES SELLS thought the Author had wrongly attributed to Mr. David Kirkaldy (p. 8) the method of applying the load by water-pressure in testing-machines, and measuring it by dead weight. Such a machine was constructed by Bramah and used at Woolwich Dockyard prior to the year 1837. This machine was used by the late Professor Barlow, Hon. M. Inst. C.E., for some of his experiments on the strength of different materials.[1] A similar machine was constructed in 1849 for the Russian Government by Maudslay, Sons, and Field, who afterwards made several others on the same principle. These different machines were made to test up to 100 tons and 150 tons.

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[1] A treatise on the strength of timber, cast iron, malleable iron, and other materials, etc. By Peter Barlow, 4th edition, 1837, p. 252, and Plates VI. and VII.

Professor KENNEDY, in reply upon the correspondence, only added that he was glad so much interesting matter had been brought forward. In reference to the remarks by Mr. Sells, he thought that Mr. Kirkaldy's name would always be the one rightly most closely associated with the type of machine referred to; but the type itself had been already successfully used in 1825, long before the date of Bramah's machine, as mentioned in his Appendix. Professor Kennedy.

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11 January, 1887.

EDWARD WOODS, President,
in the Chair.

The following Associate Member has been transferred to the class of

Members.

ROBERT WILSON.

The following Candidates have been admitted as

Students.

GEORGE HERBERT ABBOTT.
EDWARD GOULDEN BODEN.
WALTER WILLIAM BOOTH.
WALTER BOSMAN.
FRANK CONINGTON.
WILLIAM HORACE COOMBER.
THOMAS BURNSIDE CROWTHER.
EDWARD DOWNES DUPRÉ.
GUY ELLINGTON.
WILLIAM DIXON FISHER.
ROBERT GELSTON.
FREDERICK WILLIAM GODFREY.
FREDERICK HENRY GRIMSHAW.
HERBERT ROSS HOOPER, B.A.
HERBERT ALFRED HUMPHREY.
JAMES SKIDMORE JONES.
FREDERICK WILLIAM ANTHONY KNIGHT.
HENRY JOHN LAWSON.
DAVID LYELL.
DONALD MARSH MCCLURE.
WILLIAM MACGLASHAN.
JOHN CHAPMAN MOUNT.
ROBERT RICHARDSON RICHMOND.
JOHN EDWIN ROGERSON, B.A.
LINDSAY SCRUTTON.
EDWARD STOCKLEY SINNOTT.
FREDERICK JAMES WELLINGTON VEREKER.
WALTER WILSON.

The following Candidates were balloted for and duly elected as

Members.

CHARLES CHRISTISON BONE.
DANIEL MACNEE.
JULIUS PAZZANI.
THOMAS RICHARDS.

Associate Members.

James Barratt.
Hugh Walter Belcher, B.A.
Charles Brownridge, Stud. Inst. C.E.
Henry Slade Childe.
Edward Claude Hawkes.
William Wykeham Jacomb, Stud. Inst. C.E.
Robert Lyell, B.Sc., Stud. Inst. C.E.
Arthur Robert Penny.
Herbert Arthur Phillips.
William Arthur Price, M.A.
George Richard Richardson, Stud. Inst. C.E.
Walter Howard Tate.
Reginald Arthur Tatton.
William Edmond Clason Thomas.
Joseph William de Tivoli.
Harold Sebastian Vogan, Stud. Inst. C.E.
George Powell Walker, Stud. Inst. C.E.
Henry Buckler Warren.

The discussion upon the Paper on "Engineering Laboratories," by Professor A. B. W. Kennedy, occupied the evening.

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18 January, 1887.

EDWARD WOODS, President,
in the Chair.

The discussion upon the Paper on "Engineering Laboratories," by Professor A. B. W. Kennedy, occupied the whole evening.

25 January, 1887.

EDWARD WOODS, President,
in the Chair.

(*Paper No. 2229.*)

"Sewage-Sludge and its Disposal."

By William Joseph Dibdin, F.C.S., F.I.C., Metropolitan Board of Works.

Introductory.

The subject of this Paper is one of such vast importance, and the literature, published from time to time, so thorough and complete, that it is with no little diffidence that the Author, with the view of more fully discussing certain new points, has undertaken the task of condensing facts into a small compass, in order that the case may be presented in a tangible and concrete form.

Before entering upon the subject, the first impulse is to re-study the innumerable reports, papers, and other documents which have accumulated during the last thirty years, and to commence the discussion by a summary of their contents. The admirable digests, however, already before the public render such a proceeding unnecessary.

As the subject of this Paper is "Sewage-Sludge," it will naturally be inferred that it is not proposed to consider other than water-carried sewage in this connection. As that is indeed the vexed question of the hour, probably little exception will be taken to this course.

General Character of Water-carried Sewage.

One of the first questions to be considered is "What is Sewage?" The answer recently given by an eminent authority, "Sewage is variable, very variable; complex, very complex," is no doubt correct. To answer the question completely is not within the capacity of our present knowledge, and it is not intended to enter upon an attempt at its definition. It is evident that sewage must vary according to the water-supply per head of population;

quantity of subsoil water; distance it has to be carried before arriving at the works; number of times it passes through pumps, &c.

This latter consideration is one of the utmost importance, as the greater the agitation, the greater the division of the solid matters, and the consequent more solvent action of the water. The question of decomposition is one which materially affects the ultimate treatment; but in few cases, if any, is the delay in transit sufficient to allow time for decomposition to advance to any considerable extent. In any case, however, it would be most desirable if measures could be generally adopted for the immediate deodorization of fæcal matters before their discharge into the sewers. It will be readily admitted that if this could be brought about, a complete revolution would be effected in the character of all effluent waters after chemical precipitation, and many of those who look for an advance in the now imperfect methods of chemical treatment, consider that this is by no means an unpromising field to explore. Already many houses and large establishments have adopted simple means of effecting this object. When these are more widely known, as in time they must be, an enormous stride will have been made.

The main characteristic of water-carried sewage is its division into two portions, viz., the liquid and the solid. As above stated, the quantity of the latter must depend upon the treatment the sewage receives in the sewers. Great agitation means fewer solids, and those in a finely divided state. It is no doubt due to this fact, that so many persons are apt to be misled in their ideas of what sewage must necessarily be. The great diversity of evidence given before the recent Royal Commission on Metropolitan Sewage Discharge must have given rise to no little surprise in the minds of observant onlookers. By means of the systematic examination of series of samples extending day and night over months, it has been conclusively demonstrated that the average quantity of suspended matter in a dry state, in the London sewage, is about 27 grains per gallon. Reliable data, obtained from the sewage of other places, show this to be an exceptionally low figure, as in many smaller towns the average suspended matter is more than double or treble that quantity. Of the 27 grains about 54 per cent., or 15 grains, are of an organic nature. This organic portion of the suspended sewage matter consists, to a certain extent, of the undigested food of the population, and contains practically all the substances of a manurial value obtainable by means of chemical precipitation.

The liquid portion of the sewage contains in solution, on an average, about 60 grains of solid matters, 33 per cent. of which, or 20 grains, are of an organic character.

While these figures fairly represent the condition of the dilute metropolitan sewage, they by no means afford an indication of the character of water-carried sewage in other places, as stated above.

Solubility of the Suspended Matters.

The solubility of a portion of the suspended matters in solutions of lime seems to have been entirely overlooked by the numerous writers on the subject. The results of numerous experiments, made by the Author on both large and small quantities of sewage liquid, have fully demonstrated this fact. The use of an excessive quantity of lime, while affording a rapid settlement of the sludge, and a more or less clear effluent, dissolves a by no means inconsiderable quantity of the offensive matters previously in suspension, and this is apt to render the last state of the liquid worse than its first.

In proof of this statement, the Author submits the following results of a special experiment made for the purpose of demonstrating the fact clearly. Carefully washed sewage-sludge was diffused in clean water, the mixture was agitated for five minutes and a sample withdrawn; an excess of lime was then added, and the mixture again agitated for another five minutes. If the action of the lime were purely one of precipitation, no increase should have been observed in the soluble matters previously in the water. The limed liquid, however, instead of containing less dissolved oxidizable organic matter, was found to absorb about three times the quantity of oxygen required by the unlimed liquid. The actual result being:—

Experiment to ascertain the effect of Lime upon Sludge.

	Oxygen absorbed from Permanganate in 4 hours.
Aqueous extract of thrice washed sludge (filtered through paper)	0·23 grain per gallon.
The same, after the addition of lime, agitation for five minutes, and filtration through paper . .	0·71 ,, ,,

The well known objectionable character of the liquid pressed from sludge, which has been treated in the usual way with lime, is a striking instance of its action on the solid matters.

The obvious lesson to be learnt from these results is, that before

any system of precipitation is adopted for a particular sewage, care should be first taken to ascertain, that the intended process in no way exerts a solvent action on the matters which it is desired to remove. Having determined this primary point, the next question is, "To what extent are the matters in solution affected?"

Dissolved Impurities and their Partial Removal.

This point has given rise to no little controversy. Authorities on either side have differed widely, and it is only in view of the unmistakable results, obtained in the course of many experiments, that the Author ventures to set aside all statements hitherto made on the subject, and to place on record the outcome of work, specially conducted for the elucidation of this important branch of the subject.

It must be obvious to the most superficial observer, that in dealing with so variable a substance as water-carried sewage, results of an equally varying nature are likely to be obtained. If a large quantity of a soluble organic substance is diffused in half-a-pint of water, it might be thought that little trouble would be experienced in precipitating a considerable portion of it, and that with only a moderate quantity of the chemical agents suitable for the purpose. On the other hand, if the same quantity of matter is diffused in several gallons of water, it would not be surprising if the desired precipitation were not so readily effected.

This consideration is not a suggestion merely, but the outcome of actual demonstration, and it explains the cause of the various contradictory statements on the subject. To exhibit the facts in a clear light, the Author has tabulated the results of the examination of varying samples of sewage and other solutions, both before and after treatment by the usual precipitation agents employed on sewage-works (Appendix I). For the purpose of ascertaining the degree of impurity present in the samples, the quantity of oxygen absorbed by the organic matters from permanganate of potash, acting in an acid solution at a temperature of 80° Fahrenheit, during four hours in a closed vessel, has been adopted as a standard. In some cases these results have been checked by the albuminoid-ammonia process, but the former method is one peculiarly adapted for indicating the work required to be done, in the ultimate purification of the objectionable matters. The various chemicals used were first dissolved in portions of the sewage treated, to avoid errors due to the apparent removal of the dis-

solved matters which would have been indicated if the solutions had been made with clean water.

The conclusions indicated by the results given in Appendix I are tolerably clear. The first portion of the Table shows the results of the examination of 23 series, each consisting of twenty-five different effluents, obtained by as many processes, resulting from the treatment of a given sample of sewage collected from the Metropolitan system. This exhaustive examination fully confirms the statement, made elsewhere, that no practical process of chemical precipitation is capable of removing more than a limited quantity of the oxidizable organic matters in solution in London sewage.

The results further demonstrate the striking superiority of iron over alumina for sewage purification. By the use of iron sulphate in conjunction with lime, as much work is effected (on the basis of the London sewage) for £31,000 per annum as would be obtained by an expenditure of £82,000 for alumina and lime. Even when lime and alumina, with the help of only one-twentieth of their weight of iron sulphate, were added to an extent of £178,000 per annum, not so much work was accomplished as by an expenditure of only £54,000 for lime alone when used in solution. Alumina is valuable chiefly for its effect in removing some of the colour from the effluent, and thus appealing to the eyesight; while the matters actually dissolved are there nevertheless. The experiments with animal charcoal (column 17) show that when this substance was used to an extent of £182,500 per annum the benefit would be practically *nil*. The Table also indicates most clearly the danger of drawing conclusions from the examination of one or two samples only.

The second portion of the Table gives some results, which will explain the remarkable differences of opinion expressed, by various authorities, as to the percentage reduction of dissolved solids by various processes, when acting on sewage of a different character to that of London. The sewage used for this purpose was obtained from other sources, and was evidently of such a character, that the oxidizable dissolved solids were readily precipitated by even a small quantity of lime in solution, viz., 5·0 grains per gallon, no less than 52 per cent. being removed. The addition of an iron salt to the limed sewage effected a further reduction of from 9 to 17 per cent., or, in the latter case, a total reduction of the dissolved oxidizable matters of 69 per cent.

In order to test this point further, and to show that no benefit is derived from the use of an excessive quantity of chemicals,

the results of a series of precipitation experiments on solutions of clear mutton extract are given in Appendix II. The results show, that the same quantity of chemicals is capable of removing from 46 to 90 per cent. of the total oxidizable matter, according to the strength of the solution, and that a very large increase in the quantity of the chemicals used affords no advantage whatever, the results being practically the same, the differences, such as they are, being in favour of the smaller quantity of re-agents employed.

It is thus seen, that statements which have hitherto met with a great deal of scepticism on either side may be perfectly correct, the difference being solely due to the variable nature of the sewage operated upon.

These various considerations unquestionably point to the general conclusion, that where it is intended to treat the sewage by chemical means, the following rules should, as far as practicable, be observed, viz.:—

1. That the sewage should be diluted as little as possible.

2. That the flow of sewage should be adjusted, so that the agitation of the particles in suspension should be of a minimum character.

3. That unless absolutely necessary, no pumping should take place before precipitation.

The peculiar conditions affecting the metropolis are of such a nature as to recall the saying that "the exception proves the rule." The want of fall, combined with the necessity for removing the excreta from densely populous districts with the greatest rapidity, combine to insist upon a modification of these rules which are otherwise admirable.

Precipitation of Suspended Matters.

The various methods proposed from time to time for separating the sludge from the liquid sewage next invite attention. To enumerate these would require more time and patience than the recital would be worth when done. The sum and substance of nearly all of them is comprised in the use of lime, either alone or in conjunction with the sulphates of iron and alumina, or of one or both of those salts, alone or in combination with charcoal. The use of an excessive quantity of lime, whilst having a temporary antiseptic action, is objectionable by increasing the quantity of putrescible matters in solution in the effluent, as already shown. One object claimed for the use of an excessive quantity of lime, and also for some other substances, is that they destroy the living organized

bodies such as bacteria, &c., which give rise to the phenomena known as putrefaction. This question is one of such vital importance to the after character of the effluent, that it is necessary to discuss the subject at length.

The researches of Warington[1] have demonstrated, that the process known as nitrification of the complex nitrogenous bodies existing in sewage, during its filtration through land, is brought about by definite organisms, who in their life processes feed upon the sewage matters and evolve the nitrogen in the form of nitric acid. As with the nitrogen, so it is with the carbon, which is absorbed as food and evolved as carbonic acid. Without these life processes, whether they be of an animal or of vegetable nature, no destruction of the objectionable matters can take place. As the very essence of sewage purification is the ultimate destruction, or resolution into other combinations, of the undesirable matters, it is evident that an antiseptic process is the very reverse of the object to be aimed at. If a preservative process be required, a receptacle should be provided for the preserved matters; and in order to ensure that the antiseptic process should be a continuous one, any subsequent treatment or method of disposal must avoid the destruction of the antiseptic employed. In the case of lime, which in the form of strong solutions is a solvent of organic structures, what time will elapse before its neutralization by absorption of carbonic acid, and consequent loss of antiseptic properties, after the discharge of the effluent into running water? Obviously only a very limited period, after which the growth of organisms, so zealously destroyed, will recommence by reason of the numerous spores in the water of the river, and in the air with which it is constantly in contact, and there will thus be an end to the antiseptic properties of the system.

The lesson to be learnt from the numerous experiments published by various authorities, both in this country and on the Continent, is that bacteria and other low forms of organic life are most potent in the destruction of all objectionable refuse. Modern experience shows that, when this subject is better understood and thoroughly worked out, in all probability the true way of purifying sewage, where suitable land is unavailable, will be first to separate the sludge, and then to turn into the neutral effluent a charge of the proper organism, whatever that may be, specially cultivated for the purpose; retain it for a sufficient period, during which time it should be fully aerated, and finally discharge it into

[1] Journal of the Chemical Society, vol. xlv. 1884. Transactions, p. 637.

the stream in a really purified condition. This is, indeed, only what is aimed at and imperfectly accomplished on a sewage farm. It is true that knowledge on the subject is not yet sufficiently advanced to put such a system into practical operation, but sufficient is known to show that the antiseptic treatment of sewage is the very reverse of Nature's method. The Author has not the slightest doubt, but that the future treatment of sewage will be a combined chemical and biological one, as suggested elsewhere by Dr. Dupré.

If, then, an excessive quantity of lime is injurious by reason of its solvent action, and its destruction of organisms, the next question requiring consideration is, "In what manner can the action of lime, when used in moderate quantities, be best supplemented?" Before attempting to answer this question, it may be as well to consider the best method of applying lime, whatever the quantity may be, which it is desired to use. The method generally adopted for applying lime to sewage is to use it in the form of "milk of lime," in which condition only a small portion is dissolved, and the remainder is in a solid form, in which state it is chemically inactive. It cannot be too strongly pointed out, that if the whole of the chemically effective strength of the lime is to be utilized, it must be in solution and not in suspension. Whether this is brought about by first adding the lime to the sewage in the form of "milk," and afterwards agitating the sewage for a period sufficient to ensure the whole of the lime entering into solution, or first dissolving it in water, and then adding the lime-water so obtained to the sewage, matters not, the result is the same. The point being that the whole of the lime used must be dissolved. If this precaution is observed, a far less quantity of lime will be required to effect precipitation, and a few grains of lime will effect as much work as three or four times the quantity when used in the usual form of "milk of lime," without sufficient subsequent agitation of the sewage.

When it is considered advisable to increase the effect of the lime, experience has shown that either sulphate of alumina, or sulphate of iron, or, as some prefer, both of these substances in various proportions, are best adapted for the purpose. One great reason shown for the alumina salt is that it affords a less coloured effluent than does the iron; and that the latter is apt to lead to deceptive appearances when used in excessive quantities. This argument is one that requires refutation. Long and disastrous experience has now taught the public that, in the case of drinking-water, nothing is more deceptive than appearances, that often

the most cooling, sparkling draught contains the elements of death. Numbers upon numbers of self-sufficient people have succumbed, after having seen their dear ones carried off before them. Who cannot now recall instance upon instance of over-confidence in some long-used source of the daily water-supply, and equal want of confidence in the advice of medical men, resulting in that stern lesson which none can unlearn? If this is so with water, how much more does the case apply to sewage? Hold up a glass of clear liquid poison, declare it to be pure, and thousands will believe the statement; but hold up a glass of pure water with but a small fraction of clean ferruginous clay diffused in it, declare it to be harmless, and how many will turn away with a smile of incredulity? These cases, extreme as they may appear to be, illustrate only too well what may, and indeed what often does, happen, in reference to sewage effluents, and demonstrate that clearness is no more a sign of purity than is turbidity a sign of foulness.

It must not be thought, that in thus indicating a fruitful source of self-deception, the Author is not fully aware that the removal of the whole of the suspended matters in sewage is preferable to the abstraction of only a part, even although that part may be 99 per cent. The point it is deemed expedient to guard against is, that in effecting the precipitation of the last few traces of the solids, it is important that the putrescible matters in solution should not be increased tenfold the fragmentary quantity it is endeavoured to remove, in order to render the effluent perfectly bright. It is better to leave a small quantity of suspended matter in an effluent, than to increase the dissolved matters by some four or five times that amount. In order to avoid this, it is necessary that only as much lime, and no more, should be added as will do the work required. If this precaution is observed, and equal care taken with the other precipitating agents employed, little trouble will be experienced in obtaining an effluent of the maximum purity possible (even though it be not perfectly clear), together with the equally desirable result of a minimum quantity of sludge, which, by reason of the small quantity of precipitants added, will have the whole of its manurial properties, such as they are, unimpaired.

In choosing between the salts of alumina and iron, it is desirable to bear in mind the different chemical changes which take place with the hydrated oxides of these metals, when they are precipitated by the lime. Oxide of alumina is thus precipitated in only one form, viz., the fully oxidized one, in which state it remains. On the contrary, oxide of iron is precipitated in two forms, viz.,

the ferrous oxide, or lower state of oxidation, and the ferric oxide, or higher state, according to the condition in which the sulphate exists. The peculiar property of the hydrated ferrous oxide, is that it rapidly changes its condition from a lower to a higher stage of oxidation in the presence of air. The salt known as protosulphate of iron, or more generally as "green vitriol," affords the ferrous hydrate. This is rapidly converted into the ferric hydrate, by combination with the oxygen dissolved in the water. In this condition it has the remarkable power of parting with the oxygen thus taken up, and of giving it to the sewage matters. Having thus been reduced to the ferrous state, it is again ready to combine with fresh atmospheric oxygen, which it again yields up to the sewage, and, acting as a carrier of the oxygen dissolved in the sewage liquid, becomes an agent for oxidizing the more readily attacked foul matters, within the limits of the quantity used. A remarkable result, noticed in some effluents obtained by the use of a sufficient quantity of iron, is that sulphuretted hydrogen is very seldom formed, whilst in others, obtained by the use of some much-favoured precipitation agents, this objectionable gas is freely generated.

Filtration.

The alternative, so often proposed to the precipitation process for the collection of the sludge, is filtration. This system has been advocated in so many different ways, and every conceivable material proposed for it, that it would be a useless task to enumerate them. Unfortunately the outcome of them all is the same. Rapid choking of the filters; frequent cleansing; heavy manual labour; unmanageable quantity of sludge mixed with filtering material, &c. As regards the question of sludge, it is generally admitted by practical sanitarians that filtration is out of the question. As effecting the further purification of the clarified sewage, filtration is without doubt a rational process in all respects save one, and that is, expense. If further purification is desirable, and suitable land can be obtained, filtration in the form of effluent-farming is to be commended beyond all other proposals. But the land must be suitable, and not overdosed with the liquid to be purified, otherwise ultimate failure is a foregone conclusion.

Subsidiary Treatment of Effluent.

Should it be desired to effect the stoppage of the putrefactive decomposition of the soluble matters in the effluent, under circum-

stances where land is not available, other means must be sought to effect this object. A consideration of the object in view in the treatment of sewage, in addition to the remarks already made, may not be out of place at this point.

The Author has already endeavoured to point out, that an antiseptic treatment of sewage is the last to be desired; that it is against the whole plan and scheme of sewage-disposal. The object to be gained is the destruction of the sewage matters with the greatest rapidity possible. In searching for a material which will at the same time not only remove the odour peculiar to all effluents, but do so by absolutely destroying those products of putrefaction which are its source, sanitarians are limited to but very few compounds, and practically only two, viz., chloride of lime and permanganic acid. The former is unquestionably a most powerful disinfectant. But it is open to the grave objection that, after its first effects have ceased, a decidedly unpleasant odour is created by the combination of the chlorine with the organic matters of the sewage. It also creates a serious difficulty by reason of its poisonous character both to animal and vegetable life. On the other hand, permanganic acid, in the form of permanganate of potash or of soda, in the presence of sulphuric acid, is harmless; it has no odour of its own to set up in the place of the one destroyed; it is an instantaneous and complete deodorizer; and in doing its work is itself destroyed. Its method of action is the reverse of that of antiseptics, for it accomplishes its work by destroying the putrescent matters presented to it. In short, its use is the nearest approach to the practical application of ozone known to science.

But, it may be argued, the quantity of permanganate that can be added within financial limits is so small, as to be only a trifling quantity of that required to oxidize the whole of the objectionable matters in the effluent. This is true, but it only deals with the first stage of an oxidation scheme. The matters in an actual putrescent state in the effluent are the only ones which require immediate destruction, and these are but insignificant in quantity compared with the total organic matter present. Consequently the quantity of permanganate required is only a fraction of what would be necessary for the complete destruction of the whole of the organic matter. When it is remembered that a minute quantity of a strongly odoured essence is sufficient to scent a room, it will be readily understood that a small portion of actually putrescent substance will be sufficient to give an odour to a gallon of water. It is a valuable and remarkable characteristic of permanganic acid, that it exerts a selective action on those

matters which are in an advanced state of decomposition. For instance, a cold solution of fresh gelatine is but slightly affected by permanganate, but when putrefaction has commenced its action is instantaneous.

Having now treated the effluent so as to render it odourless, and stopped the immediate putrescent decomposition, by an acid solution of permanganate of soda, the means to be adopted for its further purification are next to be considered. What has been already said against the antiseptic method of treating sewage indicates the further treatment required, viz., Aeration.

Aeration.

Aeration has recently been put forward under the title of "oxidation." This is a misnomer. It is true that the ultimate object is oxidation; but if the idea is to be retained that a very partial aeration of a strongly alkaline effluent is equivalent to thoroughly complete aeration of a neutral effluent, free from actual putrescent matters, a powerful blow will be struck at the system, which, when properly carried out, is incontestably one of the utmost importance.

The ultimate oxidation is, as has previously been shown, brought about by the life-processes of various micro-organisms, and not by direct combination of the aerial oxygen dissolved in the water with the organic matters. This is the ultimate object of aeration, which must be thorough and sustained as long as possible.

Of the various systems of aerating large bodies of water when artificial means are necessary there can be little doubt, in the opinion of the Author, as to the superiority of the aquarium or "jet" system. By this means the air is introduced into the water in an exceedingly fine state of division, instead of being in large bubbles, as in the "blowing" system. The smaller the size of each air bubble, the longer will it remain suspended in the water, and thus the maximum rate of absorption will be obtained. If the site of the works allows of a sufficient fall, beyond question a series of cataracts presents the most economical and efficacious method, but when steam-power must be resorted to, the jets comprise the most elements of success, both as to space and efficacy.

The Disposal of the Sludge.

The variability of sewage-sludge is by no means an unimportant point, but one which need not materially delay the consideration of the subject. Obviously the sludge arising from the treatment

of strong sewage, which has undergone but little disturbance by pumping, &c., will have greater manurial value than the more agitated and finely-divided matters. This consideration should be carefully borne in mind when discussing the relative manurial value of the sludge of different towns.

The numerous patents, taken out for the utilization of this undesirable substance, show that the subject is one of peculiar fascination. The idea of realizing wealth is undoubtedly the cause of so much activity. On reading over specification after specification, it will be noticed that there is all but a total absence of regard for practicability and cost of working. The great idea pervading the minds of inventors seems to be that local authorities should undertake vast trading-operations, instead of strictly confining their functions to the prevention of nuisance. Such systems may be dismissed with the observation that, if an inventor has a process by means of which he can more than repay the cost of working-expenses, doubtless he will pursue the usual course adopted by business men, and, after obtaining the sludge for nothing and paying working-expenses, put a handsome sum in his pocket.

The first consideration in connection with the disposal of sewage-sludge is its bulk. This is largely composed of water, which varies from 90 to 97 per cent. Of this quantity a considerable portion can be separated, by allowing the sludge to settle in tanks specially constructed for the purpose, into which the slimy matter can be placed to a depth of from 12 to 15 feet. On standing for some twelve hours, the solid matters will be found to form a stratum about one-third below the top of the water. The top water can then be drawn off and returned to the sewage for re-treatment.

Now comes the problem—If the quantity of sludge be small, and suitable land available, by all means dig it in. This is simple and satisfactory when well done, and when sufficient earth is used to absorb all the liquid. But when the volume of sludge is large, and land unattainable, or, even if it is attainable, unsuitable, other means must be adopted. The recent successful introduction of sewage-sludge presses, for converting the sludge into a semi-dry portable form, at first sight appeared to be eminently suited for the purpose. Doubtless they are so under many conditions. If farmers are desirous of the sludge for manurial purposes, the presses are all but absolutely necessary. For small quantities they are manageable, and, as far as the subject will permit, cleanly. Evidence has been put forward in numerous Papers that the cost of pressing is about 2*s.* 6*d.* per ton. Strenuous efforts have been made to reduce

the cost, but apparently up to the present, without much success. If, however, that sum could be realized by the sale of the pressed "cake," it would be but a small matter. Unfortunately the hopes of sanitarians and agriculturists on this point seem to be doomed to disappointment, and in place of the farm, in many cases the furnace appears to be looming in the distance as the ultimate destination of the unwholesome matter.

Beyond doubt the wants of farmers should be most carefully considered. So long as they remove the sludge from the works, so long should sufficient be pressed to meet their demands; but the moment the stock increases, that moment should it be disposed of by the best means available.

When the quantity of sludge is small, a ready and economical method of reducing it to a portable condition is to mix it thoroughly with freshly-slaked lime, as for pressing, and then to run it out on to porous beds, constructed of ashes or other suitable material, such as burnt clay, and allow it to rest. The action of the lime will cause a curdling of the solid matters, the water will gradually drain away, and in a few days the sludge will have attained a consistency sufficient to enable it to be readily cut out with a spade and removed. By this means the water is reduced to some 70 per cent., as against 55 to 60 per cent. by the expensive pressing process.

Another good plan is that adopted at Southampton, which consists in mixing the semi-liquid sludge with dry road-sweepings, or ashes from a destructor furnace, in which form it is portable, and in a suitable condition for the purposes of the farmer. This system necessitates the control of the dust-bin refuse and road-sweepings by the sewage-authority. It has one great advantage in that the ammonia, which is driven off in large quantities in the process of pressing, is retained.

Having reduced the sludge to a portable condition by one of these means, its disposal, in those cases where its bulk exceeds the demands of the farmers, has still to be considered. The recent Royal Commission took the evidence of numerous experts on this point, with the outcome that they recommended the application of the sludge to the raising of low-lying lands, burning, digging into land, or carrying it away to the sea. These four systems may be considered in the order in which they are given.

The utilization of the sludge for the raising of low-lying lands is an admirable idea in the concrete. But no one having experience in exposing the wet sludge at all seasons over large areas would suggest that it should be so used in its unpressed state. If land is so raised with it, pressing must inevitably be resorted to. Here

again, comes the initial task and cost of the presses, which, coupled with the cost of transit, spreading on the land and covering with earth, make up a total so excessive, as to render the consideration of other methods eminently desirable.

Before the pressed sludge can be burnt, the water must be driven off by heat. This involves a quantity of heat greater than that obtained from the combustion of a weight of material equal to that to be dried. In other words, expense for fuel is incurred plus the cost of pressing. When the dust-bin refuse of a town is available, doubtless the object can be attained by the use of "destructors." The case of the Metropolitan sewage is, however, different, as no excess fuel is obtainable without considerable expense. The suggestion that the ammonia, afforded by the combustion of the nitrogenous portion of the organic matters, could be collected and sold for the reduction of a part of the expense, is a fascinating one. Assuming the average percentage quantity of nitrogen in the pressed sludge to be 0·87, which is the average result of a number of analyses of "cake" obtained by pressing London sewage-sludge, Appendix III, probably not more than one-half that quantity would be obtainable by destructive distillation in a closed vessel on a working scale. Laboratory experiments have shown that not more than 60 per cent. can be obtained with the utmost care. Calculated on 800 tons of "cake" per day, about £70,000 per annum might be expected as the gross return from the sale of the sulphate of ammonia, at the rate of £12 per ton. The cost of pressing, distillation, collection of ammonia, conversion into sulphate, business charges, interest on capital, &c., deducted from this sum would be such as to lead inevitably to a financial disaster. If feasible, enterprising capitalists will speedily undertake it.

Digging the wet sludge into the ground, as practised at Birmingham, would be a good plan in the case of the Metropolis if suitable land were available in sufficient quantity. The soil at Birmingham is mostly gravel, and eminently suited for the purpose, whereas that in the neighbourhood of the Metropolitan outfalls is heavy and sodden, being, in fact, marsh land. The old saying "that circumstances alter cases" applies here with full force. What is suitable in Birmingham would be decidedly unsuitable in London.

Carrying the sludge away to sea, is thus left as the only tangible and economical system available. The cost of transit is the only one to be considered. Careful estimates show that the whole expense will fall far short of that which would be necessary for the

preliminary process of pressing, independent of the further cost of disposing of the cake when obtained.

The great advantage of this method is that the sludge will never be seen. Precipitated in covered reservoirs, transferred from the precipitating tanks to special settling tanks, from thence pumped into the sludge vessel, and discharged under water far from land, the sludge will disappear in the most speedy, cleanly, and safe manner that can be devised.

The objections to this system are threefold:—

1st. Waste of valuable manure.

2nd. Possibility of nuisance on the coast.

3rd. Delay in transit by fogs and stress of weather.

The first objection is speedily met by the reply, that if the commercial manurial value of the sludge is a fact, commercial men may be safely relied upon to utilize it. They can have the sludge for nothing in any quantity. Let them take it, and deal with it as they will. This consideration applies to all propositions for the profitable utilization of the filthy matter, whatever they may be.

The second objection as to the possibility of nuisance on the coast is a mistaken one. Examine the point closely. Some 3,000 tons of "settled" sludge, equal to about 150 tons of organic matter, will be discharged per diem under water several miles from the coast. This will not be discharged at one spot, but be spread over some 30 miles. Assuming that the discharge from one vessel holding 1,000 tons, equal to 50 tons of organic matter, formed a track when diffused in the water 4 yards deep by 4 yards wide, and 10 miles in length, what would be the quantity of organic matter in that polluted line of water? Only 16 grains in each gallon. Given a gallon of water, containing 16 grains of organic matter, situated say 10 miles from the shore, and in a strong tidal way, how much offence will be given after diffusion, oxidation, the feeding of fish, &c., have acted their part, by the time it has reached the coast, if ever it does reach it? Considering that in a comparatively trifling quantity of water, as in the river, it has rarely been traced more than a few miles from the outfalls, even when mixed with all the multitudinous sources of pollution other than sewage, is it likely that the infinitesimal particles will ever be seen again when once they are fairly deposited in the great bulk of the Channel water? Furthermore, the strongest antagonist to the system cannot but admit that it is absolutely, and in every detail, fully in accordance with both the letter and the spirit of the recommendations of the Royal Commission.

The third objection, delay by fogs and stress of weather, is a trivial one. An increase in the capacity of the sludge-settling tanks, with reserve steam-power, which must be provided in any case to guard against breakdowns, will effectually overcome this difficulty. If the whole of the enormous maritime traffic of England can be carried on, as it is, with almost mathematical precision, surely the carriage of a few thousand tons of sewage-sludge to the Channel can be as readily accomplished.

While it is thus clear that in the case of the Metropolis the conveyance of the sludge to sea is the only available remedy, it by no means follows that under other circumstances, and where local conditions are favourable, other systems are undesirable. Each case must be dealt with on its own merits, and according to local requirements.

[APPENDIXES.

APPEN

APPENDIX I.—Showing the Percentage reduction of Oxidizable Organic

(All quantities are stated

Liquid used for Experiment.	Percentage reduction of dissolved Oxidizable											
	1	2	3	4	5	6	7	8	9	10	11	12
Raw Sewage from	Lime in solution 3·7	Lime in solution 5·0	Lime in solution 10·0	Lime in solution 15·0	Lime as Milk . 15·0	Lime in solution 3·7 Iron sulphate . 0·3	Lime in solution 3·7 Iron sulphate . 1·0	Lime in solution 3·7 Iron sulphate . 2·5	Lime in solution 3·7 Iron sulphate . 5·0	Lime in solution 5·0 Iron sulphate . 2·0	Lime in solution 5·0 Iron sulphate . 4·0	Lime in solution 5·0 Iron sulphate . 5·0
Metropolitan system	20	26	29	37	30	27	27	29	33	31	33	35
" "	6	10	28	64	12	10	10	18	32	27	34	32
" "	18	21	14	19	22	12	19	25	24	26	21	27
" "	26	26	26	37	10	24	25	38	33	30	31	32
" "	10	9	10	12	11	10	12	13	27	26	24	24
" "	23	29	29	34	27	23	27	35	37	33	33	39
" "	2	8	15	29	0	0	5	17	20	12	16	22
" "	12	25	30	33	25	16	22	24	32	26	30	34
" "	7	19	21	27	10	18	9	20	22	17	14	25
" "	5	12	13	18	4	5	3	11	16	13	15	17
" "	3	12	9	18	3	10	13	15	17	14	13	17
" "	15	16	19	48	44	11	15	17	20	17	21	20
" "	12	15	21	25	17	10	16	20	22	17	20	22
" "	9	15	19	23	19	11	17	20	21	18	18	19
" "	10	14	22	19	9	8	16	14	14	16	17	21
" "	12	12	17	24	12	7	12	12	22	19	19	21
" "	15	16	16	15	9	9	11	13	17	13	14	15
" "	8	8	20	35	8	11	8	14	17	14	20	19
" "	8	7	19	34	7	10	7	13	16	13	19	18
" "	3	4	4	4	9	4	4	4	8	7	6	8
" "	4	5	5	0	7	5	5	7	5	7	7	9
" "	12	20	26	28	16	15	22	23	24	23	22	23
" "	6	9	9	14	3	5	5	7	11	9	12	12
Average	11	15	19	25	13	11	13	18	21	18	19	18
Cost per annum for chemicals . . .	£ 13,505	18,250	36,500	54,750	54,750	15,695	20,805	31,755	50,005	32,850	47,450	54,750
Other sources . .	..	52	..	..	..	..	..	..	..	58	61	..
" " . .	..	..	10	..	..	..	..	..	..	..	..	56

	£.	s.	d.	
Lime taken as costing	1	0	0	per ton.
Iron	2	0	0	"
Alumina	3	10	0	"

DIXES.

Matter in Solution by various methods of Chemical Precipitation.

in grains per gallon.)

Organic matter by treatment of liquid with													
13	14	15	16	17	18	19	20	21	22	23	24	25	
Lime in solution 5·0 Iron sulphate . 8·0	Lime in solution 5·0 Iron sulphate . 10·0	Lime in solution 10·0 Iron sulphate . 10·0	Lime in solution 5·0 Alumina sulphate 5·0	Lime in solution 5·0 Iron sulphate . 5·0 Animal charcoal . 5·0	Lime in solution 5·0 Iron sulphate . 1·0 Alumina sulph. . 5·0	Lime in solution 7·0 Iron sulphate . 1·5 Alumina sulph. . 5·0	Lime in solution 10·0 Iron sulphate . 2·0 Alumina sulph. . 10·0	Lime in solution 14·0 Iron sulphate . 3·0 Alumina sulph. . 10·0	Lime in solution 15·0 Iron sulphate . 3·0 Alumina sulph. . 15·0	Lime . . . . 28·0 Iron sulphate . 6·0 Alumina sulph. . 20·0	Lime . . . . 56·0 Iron sulphate . 12·0 Alumina sulph. . 40·0	Lime . . . . 700·0 Iron sulphate 100·0 Alumina sulph. 500·0	Average.
34	36	36	33	40	32	32	34	37	39	44	49	53	34
36	38	36	32	32	33	36	67	46	45	40	43	58	33
28	30	28	15	27	19	17	25	22	23	21	28	45	23
32	36	30	26	32	30	31	30	25	36	30	30	45	30
21	25	24	16	24	14	14	16	12	29	14	26	41	19
36	36	40	37	38	38	39	33	37	39	44	55	62	36
25	28	32	16	21	19	24	22	11	26	20	24	59	19
37	41	32	24	26	28	32	29	25	31	28	43	59	30
42	25	26	21	26	19	21	16	19	22	29	31	54	22
21	22	21	16	22	21	25	25	25	26	25	25	45	18
19	21	16	14	15	13	15	16	11	14	8	18	39	15
24	25	38	24	24	25	24	26	27	38	40	46	59	27
26	25	24	16	22	25	21	21	24	22	25	40	54	22
22	32	19	23	18	19	19	18	18	20	19	18	48	20
20	20	21	21	19	16	17	22	27	19	17	21	47	19
23	23	24	15	19	17	18	22	26	25	28	39	62	21
20	11	17	10	19	15	14	15	13	17	16	17	45	16
26	27	31	20	23	18	23	28	29	31	30	41	58	23
25	26	29	19	22	17	22	26	18	29	29	40	55	20
8	10	10	0	7	7	11	12	13	12	13	29	58	10
9	7	11	0	12	11	12	13	14	11	13	16	44	10
26	22	23	22	20	20	20	22	21	25	22	33	59	23
14	13	14	10	10	11	28	18	12	12	14	19	50	17
25	25	30	18	22	20	22	24	21	26	24	31	52	..
76,650	91,250	109,500	82,125	237,250	89,425	100,375	178,850	200,750	268,275	401,500	803,000	9,672,500	..
61	69	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	33	..	..	..	..	..	..	..	..	..	..

Volume of sewage taken at 156,800,000 gallons per day.

APPENDIX II.—PERCENTAGE REDUCTION of OXIDIZABLE ORGANIC MATTER in a SOLUTION of clear MUTTON EXTRACT by CHEMICAL PRECIPITATION, as ESTIMATED by the ABSORPTION of OXYGEN from PERMANGANATE of POTASH in FOUR HOURS ACTING at a TEMPERATURE of 80° F. in CLOSED VESSELS.

Solution used.	Oxygen absorbed by untreated Solution.	Percentage reduction of Dissolved Matters by treatment of Liquid with		
		3·7 grains Lime 1·0 " Sulphate of Iron	7 grains Lime 5 " Sulphate Alumina 1 " " Iron	14 grains Lime 10 " Sulphate Alumina 2 " " Iron
	Grains per Gallon.	Per Gallon.	Per Gallon.	Per Gallon.
Solution containing 20 per cent. of clear mutton extract	100·0	90·3	90·1	91·2
" " 10 " "	50·0	87·2	87·0	..
" " 5 " "	25·0	86·7	86·6	..
" " 3 " "	15·0	83·5	82·5	..
" " 1 " "	5·0	82·2	81·2	..
" " 0·5 " "	2·5	78·4	76·4	..
" " 0·2 " "	1·0	59·0	55·0	..
" " 0·1 " "	0·5	56·0	46·0	..

APPENDIX III.—AVERAGE COMPOSITION of PRESSED SEWAGE-SLUDGE from CROSSNESS.

	Per cent.
Moisture	58·06
Organic matter	16·69
Mineral	25·25
	100·00

The organic matter contains—

	Per cent. on pressed Sludge.	Per cent. Nitrogen.
Saline ammonia	0·035	0·87
Organic nitrogen, calculated as ammonia	1·025	

The mineral matter contains—

	Per cent.
Carbonate lime	7·94
Free lime	2·45
Silica	8·08
Oxide of iron	0·97
" alumina	3·39
Phosphoric acid (= Phosphate lime 1·44)	0·658
Magnesia	traces.

(*Paper No. 2121.*)

"Filter-Presses for the treatment of Sewage-Sludge."

By William Santo Crimp, Assoc. M. Inst. C.E., F.G.S.

In breweries, sugar factories, sewage-precipitation, and other works, large quantities of semi-fluids, or of fluids containing varying proportions of solid matters held in suspension, are produced; and it is often necessary to separate the solids from the liquor. This object may generally be attained by means of filtration, either natural or mechanical, or by evaporation. When, however, the volume of the liquid compared with the solids is large, say 90 per cent. of the whole quantity, evaporation by means of heat derived from the combustion of fuel, is, under ordinary circumstances, an expensive method to employ, whilst evaporation by exposure to the atmosphere is often, from the situation of the works, or from other causes, inapplicable. Natural filtration, *i.e.*, filtration through a porous medium by gravitation, is also frequently inadmissible. In such cases, filtration may be speedily accomplished by pressure, applied through the media of specially constructed apparatus.

One form of machine in use for this purpose is the "filter-press." This machine (Plate 2, Figs. 3 and 6) is usually constructed of cast-iron plates, having recesses and drainage-surfaces on each face, the projecting rim, forming with its counterpart, when these are placed in a suitable frame, a space or cell. The surface of each plate is covered with a filtering medium of jute- or hemp-canvas, or other material (Fig. 3), and, on filling the cell with the sludge to be treated, and applying pressure, either by pumping more of the material to be filtered into the chamber direct, or by interposing an accumulator between the pump and the press, to accomplish the same purpose with a more uniform pressure, the liquid is forced through the filtering medium, and, passing along the drainage channels, escapes at the bottom of each plate, the solids being retained in the cells. When the liquid ceases to flow from the press, it is opened, and hard cakes are discovered, consisting of the solids separated from the original material treated, together with a varying percentage of moisture. In this Paper, attention will be particularly directed to the filter-press, as now adopted in various sewage-disposal works; the Plate 2, Figs. 1, 2, 3, 4,

5 and 6, show the types in use. An examination of the records of the Patent Office indicates that of late years much attention has been directed to this machine, a great number of patents having been taken out for improvements and for new kinds of presses. Notwithstanding this fact, the cast-iron plate, type 1, now in general use, differs but little from the earliest examples in use over ten years ago at Aylesbury and elsewhere. It will be observed that the plates of type 1 (Figs. 4 and 5) differ from type 2 (Figs. 1 and 2), in being of cast-iron in one piece, whilst type 2 is built up of a wrought-iron or steel diaphragm, with a separate ring for the formation of the cell. In the case of the cast-iron press, some difficulty has been experienced in consequence of the holes forming the means of communication between the cells becoming occasionally blocked by an agglomeration of solid substances, thus equilibrium being destroyed, the pressure on the plates of 90 lbs. per square inch, which is sometimes used, has been sufficient to destroy the plates by forcing the diaphragm from the rim. To remedy this defect, Johnson's plate has three bosses cast near the central hole; but these bosses proved so destructive to the cloths, that it was thought advisable to cut off those used by the Author, and risk the occasional breakage of a plate. Before doing so, however, the Author introduced screens in the sewage tanks, through which all the materials to be treated must pass, thus intercepting large substances, and obviating the necessity of studs. In plates of this class, where the filtering-medium is forced to fit the deep recess, it becomes rapidly deteriorated in consequence of the strain induced near the bevelled rim, and hence filter-cloths become an expensive item in the process. Type 2 differs in having a separate ring, and thus the cloth lies practically flat on the face of the diaphragm, and in consequence is subject to little strain. It is obvious also that a plate approaching the square form, will be more economical as regards cloth than the round, since the cloth is manufactured in rolls, and as an equal length is required in both cases, a larger surface is utilized in presses having square plates than in those with round.

Before leaving this part of the subject, further reference should be made to the modes of introducing the material to be filtered into the press.

Where the liquids contain comparatively small amounts of suspended matters, the mass is frequently pumped into the press by direct-acting pumps. But in the case of sewage-sludge, this method has not acted satisfactorily, as the sludge is so largely composed of grit and other sharp mineral matters, as to induce excessive wear

and tear of the pumps when pumping against pressures of 50 lbs. to 90 lbs. per square inch, such as are necessary for rapidly expressing the liquid. An iron vessel is therefore interposed, into which the sludge is either pumped or otherwise introduced; the vessel is provided with a dip-pipe reaching nearly to the bottom, and, on applying pressure at the top of the contained mass, it is forced up the pipe and into the press.

At Aylesbury, steam was at one time applied direct from the boiler, for the attainment of the object referred to; but an air-pump is at present employed for the purpose, and the pneumatic system is now in general operation when sewage-sludge is treated.

With regard to the use of the filter-press for the treatment of sewage-sludge, the Author proposes to describe the arrangements adopted by him at Wimbledon (Plate 2, Figs. 7, 8, and 9); but, as the quantity to be dealt with must in all cases be first ascertained, the Author, by means of careful measurements, is enabled to give the amount produced at Wimbledon, and also, through the courtesy of the gentlemen whose names are given in Appendix III, of some other towns, as under:—

SLUDGE with 90 PER CENT. of MOISTURE PRODUCED DAILY PER 1,000 PERSONS.

Name of Town.	Population draining to Works.	Ordinary flow of Sewage in gallons per diem.	Chemicals used, in grains per gallon.		Sludge per 1,000 persons.	
			Lime.	Sulphate of Alumina.	Cub.yds.	Tons.
Birmingham . . .	490,000	13,000,000	17·4	..	1·19	0·95
Bradford	188,000	7,300,000	16·0	..	1·20	0·96
Burton-on-Trent . .	34,500	4,500,000	13·2	..	1·16	0·93
Chiswick	17,000	482,000	7·0	5	1·34	1·07[1]
Edmonton . . .	25,000	900,000	Hillé	..	..	..
Leeds	320,000	10,000,000	15·68	..	0·39	0·32
Leicester	132,000	7,000,000 to 9,000,000	19·16	..	1·04	0·83
Wimbledon . . .	24,500	700,000	10·0[2]	6	1·79	1·43

It will be observed that the results differ somewhat widely, and

[1] With reference to this valve, the Author has recently ascertained that the daily production of pressed sludge at the Chiswick Works amounts to 6 tons, equal to 30 tons of normal sludge. The population is said to be twenty thousand, and the wet, or normal sludge, 1·5 ton per thousand persons daily. The particulars in the Table were supplied before the presses were erected.—W. S. C.

[2] Normal quantities.

are due to causes other than the amount and nature of the chemicals used in the treatment of the sewage. The quantity given for Leeds is particularly striking, and cannot be accounted for solely by the fact of the separate, or pan-and-pail system, being largely in operation in that town. Wimbledon is purely a residential suburb of London; there are no manufactories of a nature to affect the question, and the houses with solitary exceptions are provided with water-closets, and are connected with the sewers. The sewage, after the chemicals have been introduced, is received in settling-tanks, where the solids subside, the clarified effluent being drawn off from the top by Alsings automatical valves. After each tank has been charged, and the effluent has been drawn off, the sludge is swept into a reservoir A, constructed for its reception (Plate 2, Fig. 8). As the water cannot be drawn down to within 3 or 4 inches of the surface of the sludge without disturbing it, and allowing some of it to escape with the effluent, the sludge, as swept from the settling-tanks, contains considerably more than the normal 90 per cent. of water. The solids, however, quickly subside in the sludge-tank, and the supernatant water is drawn off by means of a sluice at B (Fig. 8), and is conveyed, together with the expressed liquid from the filter-presses, back into the pump-well, where it mixes with the sewage proper. It is important that the water should be thus drawn off, otherwise it must be passed through the presses, subjecting the filter-cloths to undue wear and tear, and also entailing extra labour and expense. It is also of the greatest importance to return the expressed liquid for further purification, since this is of a very foul description—although clarified—and inadmissible into a fully clarified effluent.

Normal sludge is, as a general rule, composed of 1 part of mineral and organic matter, and 9 parts of strong sewage. A cubic yard of sludge, according to experiments made by the Author, weighs practically 16 cwt., so that to convert cubic yards into tons, deduct one-fifth, and, conversely, to convert tons into cubic yards, add one-fourth. A cubic yard of broken cake, as taken from the press, weighs 12 cwt. As percentages of moisture will frequently be referred to, the Author has prepared a Table[1] showing the loss in weight at varying degrees of dryness; also a diagram (Plate 2, Fig. 10) which shows the same thing graphically. The following simple rule[2] was used in compiling the Table:—

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[1] Appendix IV.
[2] "Sewage Disposal," by Henry Robinson, M. Inst. C.E. 1880.

Let W = the original weight of the sludge.
" P = percentage of moisture remaining in the pressed sludge.
" X = weight of the sludge when pressed.
Then—

$$X = \frac{10\ W}{100 - P}.$$

EXAMPLE.—What will 85 tons of sludge weigh when pressed (or dried) to 55 per cent. of moisture? 10 W = 850, and 100 − P = 100 − 55 = 45, and $\frac{850}{45}$ = 18·888 tons, Answer required.

Before describing the sludge-disposal works at Wimbledon, it may be well briefly to review the circumstances which led to their construction.

In the early part of 1883, the Author was instructed by the Local Board to report on the best method of disposing of the sludge at the sewage-farm. It may be inferred that the usual difficulties attendant on the presence of large accumulations of sludge, common to most sewage-works where chemical precipitation is employed, were experienced at Wimbledon.

Residences existed within a distance of 150 yards from the sludge-pits, and a main road to London was even nearer. With a rapidly increasing population, and a corresponding augmentation of the volume of sewage and sludge, it became imperative to take steps to remedy what would soon become a formidable nuisance. The sludge was at that time swept from the settling-tanks into large filters, composed of sifted ashes, well under-drained; ashes collected from the ash-bins were also mixed with the sludge, and when the compost was sufficiently solidified, it was carted on to the land (of which there are now 72½ acres), and ploughed in. Careful observation of the drains, however, proved that small quantities only of highly polluted moisture passed through the filters, and that, it is needless to point out, was of a most foul description, by far the greater portion of the water passing away by evaporation; consequently, during wet periods, when the atmosphere was fully charged with moisture, the drying process was much retarded. For instance, after exposure of the sludge in these filters, from September 1883 to March 1884, a period of upwards of six months, the sludge still contained about 77·5 per cent. of moisture, being in a sloppy and very offensive state. The rainfall during that period was 12 inches. Exposure of sludge, deposited in the filters from April 1884 to

September 1884, or for five months, resulted in the material drying down to 71·27 per cent., the rainfall having been 7·71 inches.

The cost of carting this sludge an average distance of 450 yards was 2*s.* 1½*d.* per ton; this sum included labour, horse-hire, wear-and-tear of plant and of roads; the cost may appear high, but it must be remembered that, in its sloppy state, ½ ton only can be conveyed in ordinary carts, and there was a considerable amount of wear-and-tear on the roads. The cost of spreading as a top-dressing was 1½*d.* per ton. The crop of mangolds taken from the land, which had received dressings amounting to 240 tons per acre, was only an average one of 32 tons per acre. A repetition of the process on the same field resulted in a crop taken off in November 1884, weighing 23 tons to the acre. It is needless to say that, in consequence of the enormous quantities of filth placed on the field, it was rendered unfit for the purification of sewage. But the sludge had to be disposed of, and no farmer would take it, hence these heavy dressings. It is obvious that its value as a manure was extremely low. At that time, however, time only was used for precipitating the solids in the sewage. The whole operation of disposal was a most offensive one.

As the Author had to report on the best methods, he of course had to inquire into other systems of disposal. The Birmingham method of digging in was inapplicable, as the land at Wimbledon is not sufficiently porous. At Brentford it was intended to dry the sludge by the application of heat. The settling-tanks were constructed with double bottoms, the upper one being of cast-iron; the space between them communicated with a boiler at one end, and with a chimney-shaft at the other, forming a flue. The solids in the sewage were precipitated upon the iron bottom. It was thought that the heated gases passing through the flue, would cause the water in the sludge above to be evaporated. The Author visited the works twice, and on both occasions found a fire burning in the base of the chimney-shaft, there being not sufficient draught, in consequence of the gases becoming cooled in the flues, to make steam in the boiler, and the heat was altogether insufficient to effect the desired purpose; filter-presses are consequently now erected for the treatment of the sludge at this place. With regard to evaporative methods generally, success is dependent on the economical application of heat, together with efficient measures for the prevention of nuisance due to the offensive vapours given off. Different types of machines may be found in operation in some of the large northern towns, in which are treated excrementitious and other refuse-matter collected

from dwellings and from other places. The greater portion of the moisture is evaporated, and a more or less valuable manure in the form of "poudrette" is produced. As regards this method of dealing with sludge, the cost of treatment will obviously depend, to a large extent, on the cost and amount of the fuel consumed, and this again will depend on the percentage of moisture in the material to be dried both before and after admittance to the machine.

Although a consideration of this part of the subject may scarcely be admissible in this Paper, the Author feels that, for the purpose of comparison, the Paper would be incomplete without some reference to it.

It will be assumed, therefore, that the sludge passes into these drying-machines as it does into the filter-press, containing 90 per cent. of moisture. In a Paper read before the Second Annual Conference on the Health and Sewage of Towns, 1877, the subject being the "Treatment and Utilization of Night-soil, and conversion into a Concentrated Manure by Milburn's Drying Machinery,"[1] full particulars are given of Milburn's machine, and it is stated that in that machine 1 lb. of fuel (coke) evaporated 6·80 lbs. of water. Can such a result be relied on for continuous work? The Author prefers to take 6 lbs. of water per lb. of fuel as a standard. Adopting that number, the amount of fuel required to reduce 100 tons of sludge with 90 per cent. of moisture, to 20 tons with 50 per cent., the normal condition of filter-press cake, would be $\frac{80}{6} = 13\frac{1}{3}$ tons. The Author has proved by experiment, that the same work may be performed, by means of a filter-press, with a consumption of $\frac{1}{3}$ of a ton of coal. There are, however, other matters to be taken into consideration before the relative cost of the system can be ascertained. In all towns, the ash-bin refuse as collected is composed largely of combustible matters, and the heat generated by its combustion may be utilized in various ways. Well-designed furnaces, having this object in view, are in operation in several places, notably at Letts' Wharf, as constructed by the Corporation of London. The furnaces are termed "Destructors," those referred to being of the "Fryer" type.[2] At Bury the same kind are used, and in both cases the heat generated is utilized by multitubular boilers, through which the heated gases pass. Mr. J. Cartwright, M. Inst. C.E., of Bury,

[1] Journal of the Society of Arts. Vol. xxv. (1876-77), p. 630.

[2] "The Burning of Town Refuse at Leeds," Minutes of Proceedings Inst. C.E. vol. lxviii. p. 292.

informed the Author that 16 tons of refuse were consumed daily, and that an 8 indicated HP. horizontal engine could be effectively worked for twenty hours with the steam generated. Taking coal at 4 lbs. per HP. per hour, 640 lbs. of this fuel would perform the same amount of work; and, coal being equal to 1, ash-bin refuse as a fuel would be in the ratio of 0·015 only.

In his excellent report on the "Disposal of Refuse," Dr. Sedgwick Saunders gives statistics in reference to these destructors, and by employing the method of calculation as above, the value of the refuse is 0·012, and the means of these estimates show that 1 lb. of coal is equal to 74 lbs. of refuse. The actual value must of course vary with the nature of the refuse.

At Bury, the amount of ash-bin refuse collected daily is equal 0·23 of a ton per thousand persons; and as the average volume of sludge yielded daily per thousand exceeds 1 ton (see Table I), it is obvious that large quantities of coal must be used, in addition to the refuse, if it is desired to dry the sludge by the application of heat.

At Wimbledon, the daily amount of refuse collected is equal to about $\frac{8}{10}$ ton per thousand; and at Richmond, according to Mr. W. Brooke, Assoc. M. Inst. C.E., over a ton. Taking the mean of these figures, it would be necessary to add to the refuse about $\frac{1}{3}$ ton of coal for each ton of sludge dried down to 50 per cent.

At Salford and at Ealing, the sludge is calcined. At Ealing a "destructor" is employed, and at Salford special kilns have been designed for the purpose. But, in both cases, the sludge is exposed until a considerable amount of the moisture has passed off. It is precisely this system of exposure, with its generally attendant malodorous accompaniments, which has brought so many sewage-disposal works into evil repute; and it is a system non-existent in cases where filter-presses are employed. The well-known method introduced by the late General Scott is also one of calcination, in conjunction with exposure, and with regard to this method generally, although it may with advantage be employed in certain cases, there are large numbers of others where it is altogether inadmissible.

The application of the filter-press for the treatment of sewage-sludge is not altogether new, since it has been in operation at Aylesbury for upwards of ten years, and it is satisfactory to find that of late its adoption is becoming general in sewage precipitation schemes. The works, as designed by the Author, and now in operation at Wimbledon (Plate 2, Figs. 7, 8 and 9), are as follows:—

(1.) A reservoir, into which the sludge from the settling-tanks is swept.

(2.) A building containing the filter-presses and accessories.

The sludge-reservoir has a capacity of 130 cubic yards, and is constructed of Portland cement concrete, composed of 1 measure of cement to 6 measures of Thames ballast. A 6-inch iron pipe communicates with it and the sludge-receivers. As before pointed out, it is provided with a sluice-frame, in which are placed movable strips of wood; by removing these as required, the supernatant water may be drawn off, thus relieving the presses from unnecessary work.

The presses are two by S. H. Johnson and Co., each having twenty-four plates, 36 inches in diameter, the cells admitting the formation of cakes 1¼ inch in thickness. Each press contains 0·55 cubic yard of cell space. The plates are machine-surfaced on all the bearing-faces; the screw standard is provided with a 4-inch steel screw, having square threads of 2½-inch pitch; the side-bars are 6 inches by 2 inches, and are sufficiently long to admit of the plates being separated to the extent of 15 inches for the purpose of removing the cakes of pressed sludge. An air-compressor and a steam-engine are provided, and are of the following dimensions:—

Air-compressor, trunk type, cylinder 9 inches in diameter, length of stroke 9 inches, water-jacketed; steam-cylinder, 9 inches in diameter; length of stroke, 12 inches. The steam- and air-cylinders are fixed on a cast-iron bed-plate, parallel with each other, with a flywheel 6 feet in diameter, and weighing 22 cwt., between them. A Cochrane patent vertical boiler is provided, its dimensions being as follows: height, 7 feet 9 inches; diameter, 3 feet 9 inches. It is furnished with fifty-four 2-inch cross-tubes. Steam is also laid on from the sewage-pumping station, distant 50 yards, and in consequence the Cochrane boiler is rarely used. The cost of the works has been £1,800; the contractors being Cooke and Co., of Battersea.

In order to save time, and the expense and trouble of pumping, the works were designed so as to admit of the sewage gravitating into the receivers, which are provided in lieu of pumps for introducing the sludge into the presses. Although the Author has had no experience in pumping this material against such pressures, 50 to 60 lbs. per square inch, as are generally employed in pressing sludge, he is convinced that the gritty components of sludge must prove very destructive to pumps. Moreover, with the pneumatic system, the provision of a separate air-receiver admits of

air being stored for use when most required, viz., when newly charging a press after removal of the cakes, thus effecting a great saving in time; for about two-fifths of the total quantity of sludge treated at each operation is forced into the press in the space of fifteen seconds, the remainder of the charge requiring from thirty to forty minutes. At the same time, it is not claimed for compressed air that it is an economical agent, when used in conjunction with pumping-appliances. For instance, as an ordinary day's work, 40 tons of sludge are forced into the presses, against a mean pressure of 55 lbs. per square inch, the engine working for ten hours. The force employed is equal to that required to pump the same weight of water over a stand-post 128 feet in height. The weight lifted is equal to 149·33 lbs. per minute, and $\frac{149 \cdot 33 \times 128}{33{,}000}$ $= 0 \cdot 578$ the HP. developed in useful work performed.

The indicated power of the engine is 3·46 HP., and the ratio of useful work to the indicated power 16·73 per cent. There are the usual losses due to changes of temperature in compression and expansion, and also, what is of greater importance, each charge of air in the sludge-reservoir, when this is emptied of sludge, must be allowed to escape before the vessel can be recharged. This charge of air is at 60 lbs. pressure, and could be utilized in various ways if desired, thus considerably lessening the waste.

It should be mentioned that it is necessary to add lime to the sludge immediately before it is to be forced into the press. Mr. W. Dawson, Assoc. M. Inst. C.E., of Leyton, has tried sawdust, ashes, and a variety of other substances as a substitute, but without success. At the same time, when the repellent attitude of lime as regards ammonia is taken into consideration, it is hoped chemists may discover a substitute capable of rendering the sludge-cake of greater value as a manure. The Author experimented with different kinds of lime, and with varying amounts, and found that it is absolutely necessary that the lime should be perfectly fresh when used; that it is more economical to use ground lime than lump; and that grey chalk lime is the best. He also tried Kimmeridge carbon, and found good cakes were produced in about two hours, as against forty minutes when using lime. Chloride of lime has also been used, and gives good results when 12 lbs. are added to each charge.

The rate at which sludge may be pressed depends to a large extent on the quantity of good lime or other agent used. The standard amount used with each charge has been fixed by the

Author at 62 lbs. for Wimbledon sludge. It may be remarked that no difference has been perceptible in pressing sludge, whether it be a day or a fortnight old, nor whether the sludge be that from the lime process, or from the lime and alumina process. Different kinds of canvas were also tried as the filtering medium, and eventually flax canvas, at about 4½*d.* per yard, 40 inches in width, has been adopted.

The mode of working is as follows:—The lime is mixed with sufficient water in a tub to make it of the consistency of cream, and is poured into the hopper fixed on the sludge-pipe. The valve in the sludge-tank is then opened, and the mixture of lime and sludge gravitates into one or other of the receivers. When full, compressed air is admitted at the bottom of the receiver; this, in expanding and passing upwards through the mixture, violently agitates it, until the lime is thoroughly incorporated. Pressure is now applied at the top by means of compressed air, and the mixture is forced up the dip-pipe into the press, where the separation of the liquor from the solids is effected. When the liquid ceases to flow the press is opened, and the cakes of sludge are removed, the whole operation occupying about one hour. Two men are constantly employed, the ascertained cost of working for one week, during which period 50 tons of sludge cake are produced, being as follows:—

	£.	s.	d.
Wages	2	5	0
Lime, 50 cwt. at 1*s.*	2	10	0
Coal, 16 cwt. at 9*d.*	0	12	0
Cloths	0	16	0
Oil and Incidentals	0	2	0
Total	£6	5	0

and $\frac{125s.}{50 \text{ tons}} = 2s.\ 6d.$, the cost of producing 1 ton of sludge-cake, irrespective of depreciation and interest on the original outlay.

The annual repayment in respect of the cost of the works is £104 1*s.* 10*d.*, and adding £21 for repairs, the additional cost is 1*s.* per ton, taking the present annual production of sludge at 2,500 tons. Thus the total cost is 3*s.* 6*d.* per ton of cake.

All the sludge precipitated from the sewage is pressed, the present production, as stated above, being 50 tons of cake per week, containing a little over 50 per cent. of moisture, or nearly 24·5 tons if all the moisture were evaporated. The quantity of wet sludge is 250 tons. As the inhabitants now number twenty-four thousand five hundred, a convenient standard of 1 ton of dry

matters per week per one thousand persons may be adopted for such towns as Wimbledon, and where a similar process of sewage treatment is in operation. From January 1885 to the end of September 1886, 4,170 tons of sludge-cake were produced from 20,850 tons of wet sludge, the total quantities of chemicals used in precipitation and in pressing being as follow:—

	Tons.
Lime	446
Sulphate of Alumina	104
Carbon	30
Total	580

or as nearly as possible 0·91 ton daily. The population of Wimbledon is rapidly increasing, and the mean number of inhabitants draining to the works, since the erection of the presses, has been twenty-two thousand five hundred. The daily quantity of chemicals used in precipitation varies with the condition of the sewage and of the weather, the normal quantity being as given above. As quantities of road detritus are carried into sewers where the separate system of sewerage is not in operation, it should be mentioned that at Wimbledon very little surface-water is admitted to the sewers, nearly all the roads being provided with duplicate means of drainage. The estimate, therefore, of 1 ton of dry solids per week per one thousand persons must be modified in towns where the same conditions do not obtain. In the case of the Metropolis, assuming the present population draining to the outfalls to be three million eight hundred thousand, the amount of pressed cake produced daily, calculated upon this basis, would be 1,086 tons, or 186 tons in excess of the estimate of the Royal Commission on Metropolitan Sewage Discharge.[1] The actual amount would doubtless be less, in consequence of the small quantity of lime used; but, on the other hand, road detritus must form a considerable portion of the solids in wet weather. Taking the amount at 1,000 tons per diem, the cost per annum of pressing would, in the opinion of the Author, amount to £45,000, exclusive of the charge on capital account.

It now remains to consider the question of the final disposal of sludge-cake. It is a manure, and as such should be applied to land. Its chemical constituents will depend on the nature of the sewage treated, and on the character and amount of the chemicals

[1] Royal Commission on Metropolitan Sewage Discharge: Report 1884, page lvi.

used for that purpose. In order that the Paper may be more useful, the Author has quoted, in Appendix I, the analyses given in the report on Glasgow sewage, 1879, by Dr. Wallace.

The question of the manurial value of sewage-sludge has also been fully investigated by Dr. J. M. H. Munro, Professor of Chemistry in the College of Agriculture, Downton, Salisbury. The results arrived at by him have been embodied in a Paper, and read before the Society of Chemical Industry.[1]

In conjunction with Mr. Snook, the Manager of the Wimbledon Sewage Farm, the Author has, during the past two years, carried out a series of experiments in order to ascertain if possible the value of pressed sludge. An analysis of Wimbledon sludge-cake, by Professor Munro, is given in Appendix II. The plots experimented upon were contiguous to each other, the subsoil, 18 inches below the surface, being stiff clay. As is well known, the summer of 1885 was one of excessive drought. The crops experimented upon were mangolds, swedes, potatoes, cabbages, and permanent pasture, and the sludge-cake was tried in conjunction with farmyard manure and superphosphate. The farmyard manure was of excellent quality, and quite rotten. The sludge-cake was spread on the land as it came from the presses, and was then ploughed in, as in the case of farmyard manure. The crops from each plot were set aside as taken up, and were carefully weighed, all of a like nature being taken up on the same day. The quantities of manure applied per acre were as follow:—

	Tons.	cwt.
Farmyard manure	16	0
Sludge-cake	16	0
Superphosphate	0	5

The weights of the crops yielded are given below, the results being tabulated in tons per acre.

Manure.	Potatoes.	Hay as carried.	Mangolds.	Cabbages.	Swedes.	Average.
Sludge-Cake . . .	15·35	2·94	23·84	20·35	3·30	13·15
Superphosphate . .	12·14	2·50	25·18	20·62	2·59	12·60
Farmyard manure. .	12·50	2·63	26·16	17·77	2·32	12·27
Unmanured . . .	14·46	1·74	23·06	18·48	0·87	11·72

A comparison of the unmanured series with the manured

[1] The Journal of the Society of Chemical Industry. Vol. iv. 1885, p. 12.

shows that considerable amounts of unexhausted manure existed in the soil at the time the crops were put in, and in order to determine the amount, the whole of the plots were cropped with cabbages on the removal of the crops enumerated in the Table, with the result that the plots manured with sludge-cake yielded 21·20 tons per acre, farmyard manure 15·40, superphosphate 14·30, and the unmanured 12·50. The plots being required for sewage treatment were unavailable for further experiments, but taking the results as they stand, it will be seen that sludge-cake occupies the first place, followed by superphosphate and by farmyard manure, whilst the crop which realizes by far the largest amount per acre—potatoes—is, in the first case, much in excess of the others. In another experiment, where a dressing of sludge-cake similar to the above was placed on permanent pasture which had not been manured for years, the result was very striking, the hay carried from the manured plots, at both the summer and the autumn cuttings, exceeding by 100 per cent. that from the unmanured.

With regard to the physical characteristics of pressed sludge, the cakes, as taken from the presses, vary in hardness and toughness according to the amount of moisture remaining. If pressed to about 54 per cent. of moisture, the cakes are much more readily broken up than when pressed to 50 per cent. or less. When pressed very dry, the cakes are of a tough intractable nature, and not suitable as a manure unless well broken up. This latter operation is rather troublesome, if the cakes are not further dried to about 30 per cent. of moisture, in which condition the cake is pulverulent. On grass lands, in hot weather, the drying is soon effected, and the manure may be reduced to powder by the application of a light roller. On ploughed lands, however, where the soil is worked in the ordinary manner, clods of manure may be seen even after the crops have been removed. The soil will doubtless reap the benefit of the unexhausted manure; and the crops proposed to be grown on the experimental plots manured with farmyard dung, of loose texture and with large quantities of soluble constituents, will probably be of less value than those from the plots manured with sludge-cake.

It must not be supposed that the cake is altogether free from smell, although large quantities of it may be stored without any smell being perceptible at a distance of about 50 yards.

With reference to the chemistry of the subject, in his Paper read before the Society of Chemical Industry,[1] Dr. Munro placed

[1] The Journal of the Society of Chemical Industry. Vol. iv. 1885, p. 12.

the value of nitrogen at 12*s.* per unit, and of precipitated phosphoric acid at 5*s.* 6*d.* On that basis he estimated the manurial value of the fertilizing constituents of Wimbledon (limed) sludge at 13*s.* per ton, as delivered with 56 per cent. of moisture; and, having regard to its physical condition, he placed its commercial value at 6*s.* 6*d.* per ton. As farmyard manure at Wimbledon costs 4*s.* 6*d.* per ton when spread on the ground, the experiments made by the Author seem to a great extent to prove the accuracy of Dr. Munro's deductions.

If, however, sewage-sludge is to take and retain its place as a manure of superior class, in order to save carriage and render it more suitable for application to land, it is necessary to go further than treat it in a filter-press. The sludge-cake should be dried and pulverized, and as its quality must vary with the occurrence of storms, which bring quantities of mineral detritus into the settling-tanks, every endeavour should be made to turn out a manure of uniform quality, either by fortifying weak samples or by thorough admixture of the mass.

In a letter to the Author, Dr. Munro states that in his last year's experiments he found that "sludges containing under 1 per cent. phosphoric acid produced little or no effect when applied to crops at the rate of 1½ or even 3 tons per acre, whereas sludges containing 1 per cent. of $P_2 O_5$ produced very fair results. With specially prepared sludges, dried and ground, containing 2½ to 4 per cent. phosphoric acid, most excellent crops were grown; these sludges, in fact, were equal to many highly reputed artificial manures, and grew splendid crops of turnips, when applied at the rate of 8 cwt. per acre only."

The conclusions arrived at by the Author, after careful observation of the filter-press during the past two years, are:—Firstly, that the machine offers a ready solution to the question of the disposal of the huge masses of putrescent mud produced daily in sewage-precipitation works; secondly, that these offensive and useless masses may be quickly converted into a practically inodorous manure; and lastly, that the resulting manure is superior to ordinary farmyard manure.

The Paper is accompanied by a series of drawings, from which Plate 2 has been compiled.

APPENDIXES.

APPENDIX I.—Analyses of Air-dried Sewage-Sludge, by Dr. Wallace. Glasgow Sewage.[1]

Name of Town.	Aylesbury.	Birmingham.		Bolton.	Bradford.		Coventry.		Leeds.		Leicester.	Windsor.
Process of Precipitation.	A. B. C.	Lime.		Lime and Charcoal.	Lime.		Sulphate of Alumina.		Modified A. B. C.	Hanson's Process.	Lime.	Hillé.
		1.	2.		1.	2.	1.	2.				
Date.	1879.	1879.	1879.	1879.	1876.	1879.	1877.	1879.	1876.	1876.	1879.	1877.
Water	12·60	12·70	13·16	14·34	8·90	6·92	14·04	10·04	9·56	16·40	11·93	11·76
Organic matter, carbon, &c.	35·60	19·19	20·04	26·18	33·75	34·53	20·58	23·09	20·82	27·92	22·18	12·06
Phosphoric acid	2·11	0·40	0·72	0·62	0·80	0·73	1·56	2·07	0·64	0·75	1·21	0·87
Sulphuric acid	2·70	1·45	0·35	0·61	0·64	1·74	1·32	0·56	2·15	1·02	0·51	0·49
Carbonic acid	..	7·62	8·53	8·30	10·53	13·77	6·64	5·71	8·42	13·11	15·25	22·71
Lime	2·18	11·19	12·74	14·50	16·90	20·27	9·16	6·65	9·68	17·51	20·16	31·09
Magnesia	0·18	0·90	1·37	1·06	1·66	5·07	0·86	0·61	5·64	7·67	1·48	1·58
Oxide of iron	6·20	2·70	3·20	1·98	2·11	2·01	4·14	2·66	4·61	2·32	2·66	1·68
Alumina	6·75	2·68	2·58	2·97	3·49	3·89	4·13	5·80	7·04	6·30	1·63	2·31
Sand, &c.	33·50	41·13	37·93	29·50	21·80	10·23	37·83	42·00	31·60	7·36	22·30	14·16
	101·22	99·96	100·62	100·06	100·58	99·16	100·26	99·19	100·16	100·36	99·31	98·71
Phosphate of lime	4·61	0·87	1·57	1·35	1·74	1·59	3·40	4·52	1·39	1·64	2·64	1·90
Nitrogen	1·60	0·52	0·49	0·61	0·62	0·66	0·92	1·27	0·66	0·70	1·08	0·52
Equal to ammonia	1·94	0·63	0·60	0·74	0 76	0·80	1·11	1·55	0·80	0·84	1·31	0·63
Calculated value per ton	s. 33	s. d. 10 9	s. d. 11 5	s. d. 13 4	s. d. 15 1	s. d. 15 4	s. 20	s. d. 27 2	s. d. 14 2	s. d. 17 2	s. d. 21 7	s. d. 11 5

[1] "Sewage Disposal," by Henry Robinson, M. Inst. C.E. 1880, p. 64.

APPENDIX II.—Composition of Sewage-Sludge, by Dr. Munro.

—	Coventry (Dried).		Leyton (Dried).		West Ham (Dried).		Wimbledon, as from Press (Lime Process).[1]	
Organic matter	..	26·14	..	26·08	..	40·32	Water	56·15
Containing nitrogen	1·36	..	1·35	..	1·82	..	*Organic matter	11·36
Ash	..	..	..	..	..	..	Insoluble silicate matters	7·10
Soluble in acetic acid.								
Carbonate of lime	39·07	..	26·36	..	23·72	..	Phosphoric acid P_2O_5	1·96
Ammonia ppt. 1·49: Phosphoric acid	0·05	..	0·29	..	0·38	..	Equivalent to tri-basic phosphate of lime, P_2O_5, 4·28.	
Ammonia ppt. 1·49: Oxide of iron, alumina, and soluble silica	1·44	..	7·42	..	1·93	..		
Ammonia ppt. 1·49: Potash	trace	..	..	..	..	..		
Soluble in hydrochloric acid.								
Ammonia ppt. 9·64: Phosphoric acid	2·38	..	1·75	..	2·19	..		
Ammonia ppt. 9·64: Oxide of iron, alumina	7·26	..	7·79	..	8·09	..		
Ammonia ppt. 9·64: Potash	0·30	..	0·34	..	0·22	..		
Insoluble.								
Sand and silicates	22·84	..	26·21	..	18·30	..	Carbonate of lime, oxide of iron, alumina, magnesia, sulphuric acid, chloride of sodium, potash, &c.	23·43
	73·34	..	70·16	..	54·83	..		
Magnesia, sulphuric acid, sodium, chlorine, and loss	0·52	73·86	3·76	73·92	4·85	59·68		
		100·00		100·00		100·00		100·00
Total, P_2O_5	2·43	..	2·04	..	2·57	..		
Citrate soluble, P_2O_5	1·37	..	1·69	..	1·24	..		
Air dried as used in expl. plots.								
Water	36·23	..	21·16	..	15·43	..		
Organic and volatile matters	16·67 (containing nitrogen)	0·87	20·56 (containing nitrogen)	1·06	34·10 (containing nitrogen)	1·54		
Ash	47·10 (containing P_2O_5)	1·55	58·28 (containing P_2O_5)	1·61	50·47 ,,	2·17		
	100·00	..	100·00		100·00			

*Containing nitrogen, 0·41, equivalent ammonia = 0·50.[1]

[1] At the time the analysis was made, the sewage was treated with lime only.

APPENDIX III.—List of Towns, and names of Gentlemen who have supplied the Author with information; also their remarks on Sludge Disposal.

Town.	Authority.	Remarks.
Birmingham .	..	Cost of disposal 1*s.* 8*d.* per cubic yard (1*s.* 6¾*d.* per ton), including wages, lime, pumping, repairs, &c., but exclusive of rent, taxes, and interest.
Bradford . .	J. H. Cox . .	One-third sold, remainder tipped on vacant land adjoining the works.
Burton-on-Trent	E. Clavey . .	Deposited in earth tanks, where it solidifies.
Chiswick . .	G. R. Strachan .	Air-dried, given away. (Presses now erected.)
Edmonton . .	G. E. Eachus .	Sludge disposed of on land belonging to the Local Board.
Leamington .	W. de Normanville	With the exception of 50 or 60 cubic yards per annum, all is pumped to the land with the sewage.
Leeds . . .	T. Hewson . .	Given away, except in a very few cases.
Leicester . .	G. Gordon . .	Report of Committee, 1883, states: "We not only have huge masses of sludge, but cannot obtain a fraction from the farmers for it, nor reduce these masses appreciably by giving it away."
Leyton . . .	W. Dawson . .	Sludge pressed and given away.
Melton-Mowbray	R. W. Johnson .	Sold at a small price (6*d.*) per load, for manure, but it does not go off very readily.
Northampton .	J. H. Pidcock .	Mixed with ashes and sold as manure.
Oxford . . .	W. H. White .	Sludge goes to land with sewage. A little is removed from the carriers from time to time.
Taunton . .	J. H. Smith . .	"Sodium process." Sludge air-dried, and sold at 2*s.* per one-horse load.
Tottenham . .	W. A. H. de Pape	Delivered to and fetched away by farmers. Cost of disposal last year £424 4*s.* 4*d.*
Wrexham . .	Col. Jones, V.C.	Air-dried to some extent, and then exposed to sulphurous acid and other combustion gases from coke in one of "Gibbs' drying cylinders." The result is a dry powder, containing over 2 per cent. ammonia and 2½ per cent. bone-phosphate, which is used as a basis for artificial manure. Remainder of sludge air-dried, and used on part of the farm above irrigation-level, or sold to neighbouring farmers at about 2*s.* 6*d.* per load. The proceeds about cover expenses, and crops grown on the sludge-manured part show a profit. The sludge is used in place of farmyard manure, which is more saleable than its equivalent in semi-dried sludge, owing to difficulty of carting the latter outside the farm.

APPENDIX IV.

PERCENTAGES of MOISTURE REMAINING in SEWAGE-SLUDGE and OTHER MUDS, after the ELIMINATION of VARYING QUANTITIES of MOISTURE.

Loss of Moisture per cent.	Percentage of Moisture in Remainder.	Weight of Remainder.	Loss of Moisture per cent.	Percentage of Moisture in Remainder.	Weight of Remainder.	Loss of Moisture per cent.	Percentage of Moisture in Remainder.	Weight of Remainder.
0	90·000	100	31	85·507	69	62	73·684	38
1	89·898	99	32	85·294	68	63	72·972	37
2	89·796	98	33	85·074	67	64	72·222	36
3	89·690	97	34	84·848	66	65	71·428	35
4	89·583	96	35	84·615	65	66	70·588	34
5	89·473	95	36	84·375	64	67	69·696	33
6	89·361	94	37	84·127	63	68	68·750	32
7	89·246	93	38	83·871	62	69	67·742	31
8	89·129	92	39	83·606	61	70	66·666	30
9	89·011	91	40	83·333	60	71	65·517	29
10	88·888	90	41	83·051	59	72	64·285	28
11	88·764	89	42	82·758	58	73	62·962	27
12	88·636	88	43	82·456	57	74	61·538	26
13	88·505	87	44	82·143	56	75	60·000	25
14	88·372	86	45	81·818	55	76	58·333	24
15	88·235	85	46	81·481	54	77	56·521	23
16	88·095	84	47	81·132	53	78	54·545	22
17	87·952	83	48	80·769	52	79	52·381	21
18	87·804	82	49	80·392	51	80	50·000	20
19	87·654	81	50	80·000	50	81	47·368	19
20	87·500	80	51	79·591	49	82	44·444	18
21	87·342	79	52	79·166	48	83	41·176	17
22	87·179	78	53	78·723	47	84	37·500	16
23	87·013	77	54	78·261	46	85	33·333	15
24	86·842	76	55	77·777	45	86	28·571	14
25	86·666	75	56	77·272	44	87	23·077	13
26	86·486	74	57	76·744	43	88	16·666	12
27	86·301	73	58	76·190	42	89	9·090	11
28	86·125	72	59	75·610	41	90	0·000	10
29	85·915	71	60	75·000	40			
30	85·714	70	61	74·359	39			

[DISCUSSION.

Discussion.

Mr. Dibdin. Mr. W. J. DIBDIN observed that since his Paper had been printed he had heard some expressions of surprise that he had not entered more into detail; but if he had entered into any great detail the Paper would have been extremely unwieldy. He had been careful to deal with the question on broad principles, and had not thought it necessary to enter into minute details.

Mr. Woods. Mr. E. WOODS, President, in inviting discussion upon the Papers, said there was every reason to believe that there was a very great variety of opinion entertained on the subject, and he hoped that the speakers would compress their remarks as much as possible.

Colonel Jones. Lieut.-Colonel ALFRED S. JONES, V.C., said it appeared to him that the two Papers were of very unequal merit. That by Mr. Crimp was most practical and useful; Mr. Crimp knew exactly what he was about, and had treated his subject in the most practical manner. As to the course of experiments on which he had founded his opinion, that sludge was better than farmyard manure, he thought that it was hardly sufficiently exhaustive to warrant such an opinion; but he might say in support of these views, that he had been using air-dried sludge side by side with farmyard manure, on similar land, for fifteen successive years, without, as a rule, being able to detect any great difference in the resulting crops. Mr. Crimp had stated the cost of the pressing system very fairly and reasonably, but had shown that the expense attending it made it only applicable to rich places in confined situations, where it was an object to have a refinement upon the simple air-drying—a process which, in the open country, 300 or 400 yards from a dwelling-house, he considered to be perfectly safe. If spread out 1 foot in depth the sludge as a rule dried in a reasonable time. Describing the transfer of the sludge from the tank in which it had been precipitated into another tank at Wimbledon, it was stated in the Paper: "The solids, however, quickly subside in the sludge-tank, and the supernatant water is drawn off by means of a sluice at B (Fig. 8), and is conveyed, together with the expressed liquid from the filter-presses, back into the pump-well, where it mixes with the sewage proper." That was perfectly right at Wimbledon, but cases were common in which sewage-tanks were close to a great, wide, dark river into which the storm-water sewage overflowed, and it might be that managers of sewage-works and their subordinates, wishing to stand well with their

boards and with the auditors, who were very careful about expense, might at times find that river preferable to the pump-well. Mr. Crimp added, and all the authorities exclusively concerned in keeping down the charge on the rates would agree with him, "It is important that the water should be thus drawn off, otherwise it must be passed through the presses, subjecting the filter-cloths to undue wear and tear, and also entailing extra labour and expense." Now any manufacturing process that was unremunerative went very much against the grain of human nature, and if a thing was excessively expensive every effort would be made to do as little of it as possible, and it might be thought desirable to keep up the appearance of a beautiful scientific system, and all the while let a good deal of the material go to the river. Mr. Dibdin's Paper was a very theoretical one, and a great contrast to the other. The first theory sought to be established was that London sewage differed very much from the ordinary sewage that engineers were accustomed to deal with in other places. On that subject he should like to quote a few lines from a discussion at the Society of Arts on the 7th of May, 1886: "In the river," referring to the Thames at Barking, "there was an enormous volume of water, which exceeded the sewage to be discharged more than two-hundred fold. . . . One grain per gallon added to the London sewage represented 10 tons of material per day."[1] Now these remarks were made by Dr. Dupré, Mr. Dibdin's coadjutor in experiments on London sewage, by whom they were fully endorsed later on in the same discussion. Colonel Jones believed it was the fact, that each grain of precipitating agent per gallon of sewage would not only cost the price of 10 tons daily of the particular chemical employed, but must throw down more sludge, which had originated the theory, that the less precipitation of London sewage the better, because there would have to be such an enormous amount of sludge disposed of under any of the ordinary processes. He did not say that the theory was invented to meet that state of things, but that appeared to be the dominant idea in the mind of Mr. Dibdin. If the principle were once admitted that the effluent need only be made sufficiently clear to go into a foul river, he thought it would be getting on dangerous ground. That was the theory of the whole of the defence set up by the Metropolitan Board of Works before the recent Royal Commission, that the river was already so foul that the sewage poured into it in its untreated state could not do any harm—a defence only broken down by a personal inspection of the

Colonel Jones.

[1] Journal of the Society of Arts, vol. xxxiv. p. 669.

Colonel Jones. locality by Lord Bramwell and the Commissioners. Another theory set forth in the Paper by Mr. Dibdin was founded on the physiological fact that organic matter diffused in a very large volume of water, and exposed to light and air, became the food of minute organisms; but, of course, these organisms would leave their own excreta and their bodies in the river, or on its bed, in place of the organic matter on which they fed. He thought that Mr. Dibdin had carried that idea (p. 161) a little too far in proposing the cultivation of such animals to feed upon the sewage. The question of the space and time, in which the animals were to eat up the food accumulating at the rate of 150,000,000 gallons a day, was a rather serious consideration, but Mr. Dibdin had passed it over by simply saying, "Retain it for a sufficient period, during which time it should be fully aerated." He would ask if he had calculated how long the food would last the animals and how fast they were to eat it. It would be a very serious thing to have to find tank feeding-room at Barking, or to turn it into the river for them to feed upon, where it must oscillate about for six weeks, either in the form of sewage, organisms, or excreta. Mr. Warington, in his experiments on the nitrification by organisms existing in fertile soil, was quoted in support of this theory, but he was probably the last man in the world to expect organisms to feed without sufficient land or water on which they could have their footing. He would leave the other chemical details for others to refute, but he wished to commend the great clearness with which Mr. Dibdin had demonstrated the evils arising from excess of lime, in setting free by its solvent action organic matter, to produce that nuisance so often complained of as "secondary decomposition" in rivers which had received effluent from lime-precipitation processes. He disapproved of the passage in the Paper (p. 165) referring to the idea of putting permanganic acid into the sewage to deodorize it. It was not a new idea, because Condy's Fluid had long been used. The Author stated, in reference to the argument that the use of sufficient permanganate would be too costly, "This is true, but it only deals with the first stage of an oxidation scheme. The matters in an actual putrescent state in the effluent are the only ones which require immediate destruction, and these are but insignificant in quantity compared with the total organic matter present." Was it to be inferred that all the rest of the organic matter in solution which could not be dealt with by the very minute dose of permanganic acid—all, in fact, but an "insignificant" part—was to be put into the river beyond the reach of any further deodorizing? He also took exception to the statement (p. 168):

"The utilization of the sludge for the raising of low-lying lands is an admirable idea in the concrete. But no one having experience in exposing the wet sludge at all seasons over large areas would suggest that it should be so used in its unpressed state." Colonel Jones.

That was the very thing he had proposed to do in his evidence given before the Royal Commission, by whom it was received with some favour, namely, instead of conveying the sludge by barge from Crossness and Barking, to take it in a sewer, to spread it upon eminently suitable land at Canvey Island, and to deposit upon it common earth, the best disinfectant known, both being deposited from the sewage water itself, in exactly the same way as Nature had deposited large tracts of land at the deltas of rivers for many ages. He had experimented with alternate strata of wet sludge and earth to a total depth of 6 or 7 feet before giving his evidence, and he submitted that that was the most economical plan that could be adopted. He was surprised to find that steamers were advocated by Mr. Dibdin, because he knew that when the idea was originally introduced he had rejected it as absurd; but he supposed that the experience of the immense difficulty of dealing with such an enormous mass of sludge, in the confined and populous area of Barking, had compelled him to fall back upon any expedient however extravagant. With reference to the Table, Appendix I, he should be glad if Mr. Dibdin would explain how in practice it was intended to apply the very minute quantity mentioned in column 7 (p. 172), namely, lime in solution 3·7 grains, and iron sulphate 1 grain. How was that in practice to be applied to the ever-varying quality and volume of the sewage, and how was it to be adjusted so that the average per day or week should be exactly hit off? The Table was a valuable one, because it showed at a glance the enormous expense to which the Metropolitan Board of Works might be put in providing the tanks at Barking and Crossness. The Board had been induced to incur the expense from the idea that the chemicals would only cost £20,805 per annum under column 7; but if it was driven, as it might be, to column 22 (p. 173), the cost would amount to no less than £268,275. He would ask what figure Mr. Dibdin would arrive at for total annual cost when the price of the deodorizing permanganic acid was added to the amount he had mentioned, and also the working charges. He wished freely and thoroughly to give Mr. Dibdin all the credit due to him for his extreme ingenuity in devising a temporary remedy and expedient, by which the Board might evade the fulfilment of the absolute duty imposed upon it by the decree of the Royal Commission.

Mr. Jones. Mr. JOHN JONES as a member of the Metropolitan Board of Works, and therefore a party to the great cost that had been put upon the Metropolis, first in deodorizing, then in precipitating, and finally in making proper tanks for doing the work, observed that within a few days it had made a contract for providing tanks at Barking at a cost of £406,000, and almost an equal number would have to be put into operation on the Crossness side of the River Thames. It had been recommended by Mr. Dibdin that the sludge should be sent to the sea, and to that he strongly objected. The late wet seasons had washed a great deal of the fertility out of the light soils of England, and the country could not afford to throw away any manurial matter. Owing to railways, common roads, waterworks, and extensions of buildings, less land was available for the maintenance of the population than formerly, and there was therefore the more need for cultivation. It was possible to raise from land properly cultivated one-third more produce than was raised on the average of the land in England, but it could only be done by manures; he therefore valued very highly the sludge made in London—indeed, he considered it the safety of the population. He was sorry to hear of the project for sending it all to sea. It was true that the Board had engaged the services of one of the members of the Institution to ascertain the best kind of ship in which to carry the stuff to the ocean, but he wondered that that gentleman went on such an errand, and did not at once discountenance the idea. Sewage when pressed was a valuable manurial product. He held some of it in his hand, sulphate of ammonia produced from the cake, which was commercially profitable. It was of great importance that farmers should know what was actually in the sludge. At present they were ignorant on that point, and would not therefore put themselves to the expense of hauling the material from the stations until experiments had been made, and the Board was willing to make experiments in that direction. Mr. Jones had nothing to do with promoting companies, but he protested against sludge going into the sea instead of being used for manurial purposes. If the farmers would not use it, it could be separated into its constituent elements and made commercially profitable. There was therefore no need to trouble any further about the difficulty of disposing of the thousand tons per day yielded by London.

Mr. Sillar. Mr. WILLIAM C. SILLAR said he had always maintained that no solution of the sewage question ought to be considered perfect until it provided for the agricultural utilization of the product. Was there any one present who believed that there was no agri-

cultural value in sewage? He entirely concurred in the conclusions given in Mr. Crimp's Paper:—"Firstly, that the machine offers a ready solution to the question of the disposal of the huge masses of putrescent mud produced daily in sewage-precipitation works; secondly, that these offensive and useless masses may be quickly converted into a practically inodorous manure; and lastly, that the resulting manure is superior to ordinary farmyard manure." Those conclusions were in striking contrast to the conclusions of Mr. Dibdin, that however in other circumstances, where local conditions were favourable, other systems might be desirable, "it is thus clear that in the case of the Metropolis the conveyance of the sludge to sea is the only available remedy." He entirely differed from that opinion. Instead of being the only available remedy, it was the most disgraceful remedy he had ever heard proposed. The prosperity of every branch of industry depended largely upon agricultural prosperity, and yet Science had been evoked to extract from the land every element of fertility in it: there were manure manufactures where sulphate of ammonia and other stimulants were used more and more, so that the soils day by day were getting exhausted, the result being that landlords and tenants, wealth and poverty, were in antagonism, instead of harmonious co-operation. If people tried the experiment in their own affairs, continually drawing cheques on the bank without paying in deposits, where would they be landed at last? Just where agriculture was being landed by modern civilization. If they went on drawing the sustenance from the land, and recklessly throwing it into the sea, the sooner they gave up agriculture the better. It might be a parsimonious alternative, but it was not true political economy. He was sorry that Mr. Dibdin had arrived at the conclusion mentioned in his Paper, because many persons would follow his advice. He thought the secret of the error was to be found in the statement: "Authorities on either side have differed widely, and it is only in view of the unmistakable results, obtained in the course of many experiments, that the Author ventures to set aside all statements hitherto made upon the subject." When a writer ventured to set aside all previous statements, and all discussions that had taken place, and began at the beginning, he was not surprised that it should appear very clear to him that the only thing to do was to throw the sludge into the sea. There was one important omission in Mr. Dibdin's Paper. The whole treatment of sewage, he said, might be condensed into the use of lime; but, by the addition of lime to manure, the whole of the ammonia was discharged into the air, rendering the manure comparatively worthless for agricultural Mr. Sillar.

Mr. Sillar. purposes. Why was it that Mr. Dibdin had entirely omitted from his calculations the only precipitation process in England in which lime was not used? When asked to give evidence connected with the Aylesbury sewage-works, Dr. Tidy said: "All my evidence is hearsay, I should like to have it in my power to say that I have seen it. Will you put your works unreservedly into my hands for three months, that I may be able, with my own observation, to ascertain what truth there is in these claims which seem so extraordinary?" That was done, and for three months Professor Dewar and Dr. Tidy took the entire control of the works, and engaged the services of Mr. Ansdell to assist them. The result was that Dr. Tidy and Professor Dewar reported that the percentage of combined nitrogen in the manure was 3·8, where it was perfectly dry, and, when calculated on the manure containing 20 per cent. of moisture, 3 per cent. of available ammonia, and of phosphoric acid, 5 per cent. Now manure with 3 per cent. of ammonia, and 5 per cent. of phosphoric acid was so agriculturally valuable, that there had never been any difficulty in selling it at £3 10*s.* per ton. Mr. Crimp had stated that if 2*s.* 6*d.* per ton could be obtained, it would pay the expense of pressing. To destroy the sludge by putting lime into it, and then to treat it as a totally worthless material, was certainly not an economical method. He would now relate a little of his experience in the matter of drying, which he had gained during a period of twenty years at an expense of about £100,000. The first method adopted was to let the sludge lie upon the ground and dry in the air. During the late wet weather, the roads had themselves been in a state of sludge, yet a day or two of strong east wind sufficed to dry them. It was the same with the sludge under discussion, when chemically treated so as to separate, to a certain extent, the water from the solid part, the air passing over the top vaporized it, and part of it soaked into the ground, and in two or three days it was sufficiently dry to be pulverized. The east wind in March dried it as much as the summer heat. But the expense of picking up the material and turning it over was greater than the expense of putting it through presses. The next plan adopted was to lay out the sludge in shallow pans, and pass hot air over it, but that would not do. Then furnaces were placed under it and it was heated; but the steam rose in clouds, condensed under the roof (for it was covered in), and came back again. The fire underneath roasted part of it, which fell into the fire and made an intolerable odour. The next plan was to try Manlove and Alliott's centrifugal machines, with which very dry cake was obtained; but they were expensive, and

not always satisfactory. There was no mode of disposing of the tenacious black liquor (which might be used as ink) produced in the process. It became necessary to discard all those methods, simple as they were, because they were impracticable. Presses were then tried. The first press was one that had been used for fining wine by the Pure Wine Company. The diaphragms were made of wood, and they answered very well. An excellent cake was produced; but the wooden plates were always breaking, and the expense was prohibitory. Ultimately iron presses were adopted, which sometimes succeeded and sometimes did not. The sewage had to be pumped with great force into the presses, and as it was very gritty it wore them out. At last it was found that the simplest plan was to let the sewage lie in a closed reservoir attached to the press, and turn the live steam from the boiler into it. There was 60-lb. pressure in the boiler. That pressure was exerted by the press, and it squeezed the cakes admirably, but wishing to improve upon that, steam was discontinued and air pumps were obtained; of which, however, he did not approve, believing that the steam was better and more economical; but that was an engineering question which others could decide better than himself. With regard to the process, the sludge as it came from the city was mixed with a large volume of water, which had to be got rid of. It would not do to put it all through filter-presses. Separation must take place by precipitation, and the bulk of the water got rid of in that way. The sludge at the bottom contained 95 per cent. of water. The second extraction of water was by the filter-presses, which reduced the amount to about 50 per cent. It was not even then available for agriculture; but had to be further dried by heat. When put up in heaps, owing to the nitrogen it contained, it became heated, which dried it to a powder. It might be put through revolving cylinders and artificial heat applied, and although that was an expensive method it was sometimes worth while adopting. The material was then ready for use, but not as pressed cake, for in that form it would not go to the roots of plants. It was so light that if thrown into the air it would not fall immediately upon the ground but would be blown away as impalpable dust, although it still contained from 14 to 20 per cent. of moisture. In that condition it was available for agriculture. Sewage obtained by subsidence alone, however, was not available for agricultural purposes. The excreta of human beings consisted of solid and liquid; the manurial properties of most value were in the liquid, and Liebig considered 8*s.* 7*d.* as the value of excreta, but he gave 8*s.* for the urine Mr. Sillar.

Mr. Sillar. and 7*d.* for the dung of one person. The street-sweepings collected by boys might be put into a garden and have no effect upon it, but urine was of the greatest possible value, and when Mr. Dibdin ignored all the matter in solution in the sewage, he ignored the great bulk of that which was of agricultural value. Mr. Dibdin stated that the processes in question removed such a very small portion of the dissolved matter that they were not worth adopting. Dr. Tidy, however, stated that the A B C process removed 61 per cent. Sewage, therefore, ought not to be destroyed. No chemist would dispute the fact of clay having the power of extracting the valuable part of urine. The experiment could easily be tried. If a handful of clay were put into a bottle of urine and the mixture shaken up and dried to evaporation, and if it were put to the roots of plants its value would soon be ascertained. Dr. Tidy and Professor Dewar in their Report,[1] said, "As to the manurial value of the Native Guano, we are strongly of opinion that this must be judged rather by the practical results of the agriculturist than by presumed theoretical values based on analytical data." Mr. Sillar submitted the Tenth Collection of Testimonials sent to the Native Guano Company by the very men who had purchased the native guano and used it. They had paid 70*s.* a ton for it, and had come again fifteen or sixteen times to repeat their orders, and had declared that they never had a manure equal to it for agricultural purposes. With regard to London, supposing it to produce 200,000 tons of manure a year, that would not be sufficient to manure the county of Kent alone. In the offer made to the Metropolitan Board of Works to treat the sewage of London by the Native Guano Company, the calculation was based upon the estimate of £1 per ton to be obtained for the manure. Would any one suppose that if manure with 3 per cent. of ammonia and 5 per cent. of phosphates could be produced, £1 per ton could not be obtained for it? In that way the agriculturists of the country would obtain for £1 per ton 200,000 tons of manure, for which they were now glad to pay £3 10*s.* per ton.

Mr. Fowler. Mr. Alfred M. Fowler remarked that the observations of Mr. Sillar had reminded him of some experiments that he had been making at the Leeds works, of which he was the Engineer. £10,000 had been spent there in making the experiments based chiefly upon the A B C system, which he believed was similar to that advocated by Mr. Sillar. If all Mr. Sillar's statements were

[1] Report of Dr. C. Meymott Tidy and Professor James Dewar on the A B C sewage process, 1885, p. 6.

correct, how was it that that transaction had collapsed? The Corporation advertised the matter to the whole world, and had a special chemist to take the cost of each process, but in no case was any practical result shown in the way of making the sewage residuum pay for the cost. At present, after twenty years' trial at Leeds, it had to be given away. After all that had been said by the theorists who were at work at Rochdale, Nottingham, and other towns, and publishing accounts from day to day, how was it that the farmers did not purchase the manure? At Hastings twenty years ago he was told they were paying £3 10*s.* per ton for the A B C manure, but how was it that they did not take it now if there was such great value in it? The result was that after twenty years it had been shown that there was very little value in it, and that it would have to be given away. He thought the Metropolitan Board of Works was going in the right track. The Leeds Works had cost £40,000, the Salford Works, of which he had also prepared the original designs, had cost £100,000. In both towns the precipitating principle had been adopted, but in neither of them was a penny got for the manure. Notwithstanding what might be said, the principle would not be generally adopted unless some better practical results were shown. Mr. Fowler.

Dr. A. ANGELL said that the discussion of the question of the disposal of sewage necessarily involved to a certain extent the kind of materials used, and the method of using them for the production of the sludge. The character of the sludge was of course dependent to a large degree upon the character of the materials used to produce it. The most popular precipitant of the day—popular because easy to obtain and cheap—was lime, and Mr. Dibdin had proposed its employment in the treatment of metropolitan sewage; Dr. Angell was one of those who had the strongest possible objection to lime, which he thought ought to be removed from the list of materials to be used for the chemical treatment of sewage. One of his reasons was that it had a caustic or solvent action on organic matters. It would increase the quantity of organic matter to be dealt with, because it would act even upon the most insoluble portion of it—that which was little more than woody fibre; even paper would feel the caustic and alkaline action of lime. In consequence of its basic properties it liberated foul gases, and added to a considerable extent to the odours about the locality where the treatment took place. Then the production of alkalinity in the effluent was favourable to vibrionic forms of fermentation. Again, it caused ammonia to volatilize from the sludge, and therefore made the sludge of less Dr. Angell.

Dr. Angell. agricultural value. It should never be forgotten that, if it was intended to put the sludge upon the land, lime could not be continually added to any soil without materially interfering with its agricultural constitution—its property of producing plant-life. He thought, therefore, that the use of lime could not be condemned in too strong terms—it spoiled the effluent, it spoiled the sludge, and, in committing that act of spoliation, it created an intolerable nuisance. He did not know that it was possible to say more, except that the adoption of such methods was an act of chemical vandalism. The greater part of Mr. Dibdin's Paper, as a chemist, he agreed with; but there were certain parts from which he differed. Mr. Dibdin had spoken of alumina as a substance which was a decolorant, and therefore caused the effluents to please the eye. It was something more than a decolorant, because it was impossible to attack colour without breaking up the citadel, and when once the constitution of highly organized matters was broken up, the further oxidation by direct attacks of atmospheric oxygen, or dissolved oxygen, was a comparatively easy task. A laugh went round the room at a philosophical, scientific, and reasonable conception referred to by Mr. Dibdin, in speaking of Dr. Dupré's belief that some day there might be found a method of treating sewage biologically; of course indicating that it might be possible some day to cultivate some form of ferment which could be controlled. But it was hardly safe to laugh at such statements considering the rapid strides that science was making. He believed to a large extent the form of fermentation could be controlled, and therefore the biological action that took place in sewage. If the fermenting organisms were allowed to grow without air, they formed what Pasteur called the vibrionic form of fermentation. The products of that kind of fermentation were the most putrefactive and disgusting to the senses, and serious in regard to health. On the other hand the aerobian or atmospheric forms of life could be caused to grow—those which grew nearer the surface, as Pasteur had taught after the labour of many years. He was quite sure that Mr. Dibdin could never have intended to convey what he appeared to convey by his language in speaking of the danger of agitating sewage and breaking up solid matters. Allowing that that was a danger, it was counterbalanced by the fact that if the sewage was well aerated before, during and after treatment, it would be certain that the microbe life assumed that form which produced the least objectionable by-products. Microbes were undoubtedly swallowed with food; they had plenty of air,

and fermentation was carried on in a wholesome way in the mouth and stomach; but immediately they got into the intestines, where they had no air or oxygen, either the same forms of microscopic life, or those that accompanied them, and could not exist under previous conditions, took the upper hand, and putrefactive fermentation set in. In sewers it could be determined which party of microbes should continue to do its work—whether by thorough aerification, the least objectionable, or whether the lowest possible forms, the putrefactive or the vibrionic. With regard to the action of alumina, he had made experiments to ascertain whether or not sulphate of alumina precipitated in the presence of fresh organic matter would carry down any quantity, and in what kind of combination—whether combined or simply entangled. He had convinced himself that sulphate of alumina precipitated by ammonia in a gelatine solution carried down a large quantity, and it could not be washed away by hot or cold water without leaving behind a compound which was highly carbonaceous. A favourable reference had been made by Mr. Dibdin as to what had been done in Southampton. Dr. Angell would only mention that as a chemist he knew that sewage was being successfully treated there without lime. His own idea of a precipitant would be something of this kind. There must be some particulate material; not only the chemical character of the precipitate, but its physical properties must be studied. It should produce a sludge which it was easy to desiccate by pressure or by other means; very much unlike the quaking sludges made by lime and alumina, but which had such a consistency that farmers could use it, and which, when put upon the fields, the young grass could grow through. Those properties were only to be obtained by making use of some kind of earthy carbonized material, rich in iron and alumina, whose salts should be soluble and available. Then, in order to get reaction, there must be present the sulphates of lime or magnesia, or both. The chemistry of the action of such a substance would be that the lime of the sulphate of lime would react upon the carbonic acid of the alkaline carbonates present, and that constituted a portion of weighting precipitate in the form of carbonate of lime. Liberated, the alkalies would react upon the iron and alumina, and a coagulum would be formed, such as when alumina or iron were used. The iron must be in a ferrous condition, because of the curious reaction that went on in handing over oxygen to oxidizable matters. To be safe the material must be one that had gone through a reducing-action. All carbonized materials had gone through a reducing-action, and therefore it Dr. Angell.

Dr. Angell. was certain that all the iron was in a ferrous state. This was why he believed that some such substance should entirely displace lime. In using such a material it would be certain there would be no alkalinity, which was so conducive to the after-changes in fermentation taking place in alkaline effluents.

Mr. Bennett. Mr. W. B. G. BENNETT said that if Mr. Dibdin had arrived at the conclusion that the only available way of disposing of London sewage was to cast it into the sea, he hoped that the Metropolitan Board would hesitate before adopting his proposal, because whatever financial value the sewage might have would be lost to the ratepayers of London beyond recovery. He thought that the Author had arrived at some conclusions a little too rapidly, and that, perhaps, was owing to the large quantity of material with which he had felt himself compelled to deal. Granted that there were 3,000 or 4,000 tons of sludge to dispose of, that might indeed appear a large quantity, especially in one place; but if chemists were afraid of moving a few thousand cubic yards of stuff, engineers were not. He would say, "By all means precipitate the sludge, throw a good effluent into the Thames, and hand over the sludge to the engineers to deal with." They would soon find some method of disposing of it, without throwing it away and losing its value to the community. The scheme of Mr. Bailey Denton and Lieut.-Colonel Jones had been mentioned, and that was one example of how the sludge could be disposed of without throwing it away. Mr. Dibdin had proposed to put the sludge or sewage upon a vast area of land, and so reclaim it from the water. Referring to what was done at Southampton, he had also stated that another good plan had been adopted there; and it might not be out of place if Mr. Bennett, as the Engineer of those works, gave a brief description of what was being done there, so as to show that sludge could be disposed of otherwise than by being thrown into the water. He had for the past two years been precipitating the sewage and conveying the resulting sludge from the reservoirs, where it was precipitated, to a place of disposal a mile distant, pneumatically through a sealed main with Shone's ejectors. On the arrival of the sludge at the disposal-works, it was in dry weather mixed with the road-sweepings, and in wet weather with fine ashes from the stoke-holes of a refuse destructor. Up to the present time he had been able to dispose of every ton, so that the works were now paying their way without making the slightest increase in the rates. The power for the transmission of the sludge was obtained from the heat of the burning ashbin contents. The products of combustion passing through the boiler

raised the steam for compressing the air. Mr. Dibdin had further stated that the scheme necessitated the control of the dustbin refuse and road-sweepings by the sewage authority. In the case of Southampton that was a fact, and he thought he could show that it was a very advantageous combination of the two systems of disposal. He thought also that it would be a great improvement if the Metropolitan Board of Works would take the sole control of the ashbin contents and road-sweepings, and put an end to the system of divided responsibility that now appeared to be adopted in London; and also, instead of following the present method of erecting destructors in each district or parish, erect two large destructors, one destructor on each side of the Thames, conveying all the ashbin contents and road-sweepings to the outfall works, and so utilizing them for obtaining some portion of the steam-power for treating the sludge. Mr. Dibdin had stated that one reason against treating the sludge in any other way than throwing it into the sea, was the great expense occasioned in pressing it. Mr. Bennett thought that the ashbin contents could be so burnt that power would be obtained for treating the sludge by pressing it. At Southampton another scheme was being formulated, by which it was proposed to transmit the sludge by a sealed main across the river to an agricultural district on the other side, where a depôt would be established, so that farmers could come and load their carts with sludge, and thus save the expense of carting from the town. No presses were employed; the sludge was simply incorporated with road sweepings and dry ashes by an incorporator. That method turned out the sludge in a state of good portable manure, which was readily bought up by the farmers at 2*s.* 6*d.* per load. This was one way of treating sludge without presses, and thus saving the expense that would be thereby occasioned. About 21 tons of the ashbin contents gave when burnt something like 25-HP.; 4,000 loads, or perhaps more, of the London ashbin contents would certainly give a very great power at the two outfalls, to be utilized for the treatment of London sewage. Mr. Bennett.

Dr. C. MEYMOTT TIDY congratulated Mr. Crimp on his Paper. He did not propose to deal at length with the Paper, which certainly appeared to be a very valuable contribution to the history of sewage-sludge. With two of the conclusions he entirely agreed; first, that the machine offered a ready solution to the question of the disposal of the huge masses of putrescent mud produced daily in sewage-precipitation works; and secondly, that those offensive and useless masses might be quickly converted into a practically Dr. Tidy

Dr. Tidy. inodorous manure. As to the third conclusion, that the resulting manure was superior to ordinary farmyard manure, he offered no opinion. At present he was disposed to regard both sewage and sewage-sludge as materials to be got rid of in the fastest and the easiest possible way. Nature, if let alone, would utilize them. With reference to Mr. Dibdin's Paper, it was said to be one on the subject of sewage-sludge; he ventured to think it was essentially a Paper on sewage treatment. The Paper was a remarkable one, and needed to be read by the light of history. There was a certain Commission appointed some years ago, called Lord Bramwell's Commission, to consider three questions; first, the system under which sewage was discharged into the Thames; secondly, whether any evil effects resulted therefrom; and thirdly, if any evil effects resulted, what preventive or remediable measures should be taken to prevent the nuisance? The second of those questions formed the subject of investigation for forty-five days, between July 1882 and July 1883. It was fair to admit that Dr. Frankland and himself gave evidence as chemists on behalf of the Corporation of London, to prove that a very considerable nuisance existed; Mr. Dibdin, Dr. Dupré, Dr. Odling, and Sir Frederick Abel, being called on the part of the Metropolitan Board of Works, to prove not only that no nuisance existed, but that actually in some cases the river was benefited by the sewage. He would quote two short passages from the evidence of Mr. Dibdin and Dr. Dupré. When asked what all the statistics and facts adduced came to, Mr. Dibdin replied: "It shows at first sight that the river is not polluted with sewage or anything to such an extent as to cause a nuisance, and, independently of chemical analysis, common observation shows the same thing." And again: "The deduction which I draw in the first instance is, that the contamination of the river at that point is immaterial." Dr. Dupré—who was always a little more explicit and lengthy—stated about the facts, "I think they show that the river is quite capable of dealing with the amount of sewage discharged into it, without ever getting generally into a bad condition, and they show also, clearly, that the amount of sewage daily discharged is, upon the average, daily got rid of, otherwise there would be a progressive increase in the pollution which we have not observed, and we have observations after an interval of five years. The sewage outfalls were opened, I think, in 1865; we have the first series of analyses in 1878, and the last in 1883, so that a five years' interval is a very considerable proportion of the whole, and yet they show no progressive increase; on the contrary, as I said, 1883 is slightly the best of

Dr. Tidy.

all the years, showing, I think clearly, that the river is quite capable of disposing of the sewage that is discharged into it." In due time the Report of the Royal Commission appeared. He would read from it two extracts stated as the conclusions of the Royal Commissioners: "That in hot and dry weather there is serious nuisance and inconvenience, extending to a considerable distance both below and above the outfalls, from the foul state of the water consequent on the sewage discharge." "It is desirable we should inquire further, what measures can be applied for remedying or preventing the evils and dangers resulting from the sewage discharge." That report was not very satisfactory to the Metropolitan Board of Works, but public opinion was brought to bear upon that body. He ventured to say that if the Board could have left the matter alone it would have done so, but public opinion forced it. Whom should the Board consult to suggest a remedy for the existing state of things? It was scarcely credible, but the very chemists were consulted to cure the evil when they had said that there was no evil, no nuisance, that nothing was wanted. In perfect consistency—for the Metropolitan Board of Works was nothing if not consistent—the Board applied to the very men who had said that the patient was in perfect health to write a prescription to make him better. He had very carefully read the report of those gentlemen. It was not signed by Mr. Dibdin, but he was quite sure that he had given a great deal of attention to the preparation. It was signed by Sir Frederick Abel, Dr. Odling, Dr. Williamson, and Dr. Dupré. He would only quote one short passage from it: "We therefore recommend that the sewage be treated throughout the year with lime and sulphate of iron, in the proportion of 3·7 grains of lime and 1 grain of sulphate of iron to each gallon of sewage; that, whenever it should be found that a fairly clear effluent obtained by that treatment is to any appreciable extent offensive, manganate of soda be added to the effluent in such proportions as are found necessary to deprive it of offensive smell, those proportions to range between ½ grain and 1½ grain, inclusive of the crude commercial manganate, and sulphuric acid in quantity equal to about one-third of the crude manganate." Upon that Report there came, as an apology, Mr. Dibdin's Paper. There was a good deal in the Paper with which he of course agreed; he would not, however, deal with that portion of it, but would refer to one or two details open to question. He would not discuss the question of the quantity of suspended matter in the sewage; that had been fought out over and over again. Mr. Dibdin's statement about

Dr. Tidy. the 27 grains per gallon of dry matter was clearly an error. It was all very well to take the average sewage as containing 27 grains, but Mr. Dibdin had left out storm sewage altogether. A good deal had been learnt about storm sewage and storm overflows in the course of certain enquiries. The treatment recommended for the sewage was 3·7 grains of lime and 1 grain of sulphate of iron per gallon. He would first ask Mr. Dibdin whether the whole of the lime would not be instantly converted into carbonate of lime. He rather suspected that it would. He knew something about the carbonic acid of sewage, and he maintained that, taking ordinary sewage, the whole of the 3·7 grains of lime would be at once used up to form carbonate of lime, this acting simply as a weighting material; as a precipitating element the lime would be rendered absolutely valueless thereby. But he would allow, for the sake of argument, that the action of the lime on the sulphate of iron would be to precipitate ferrous oxide, or, as it was generally called, protoxide of iron. He admitted the value of ferrous oxide as a precipitating agent, and that it combined with the soluble organic matter of sewage to form an insoluble body, a compound of iron and organic matter of a nature not well understood. But admitting that to be the action of the iron, the quantity suggested was practically ridiculous. Taking it as dry sulphate of iron—which was not probable, for it was more likely to contain water than to be anhydrous—the quantity of ferrous oxide precipitated would be actually less that ½ grain per gallon. He had taken the trouble to have the stuff weighed, and he exhibited ½ grain of iron oxide—the amount which was to be added to a gallon of water. Mr. Dibdin had, however, stated that that was not the action of the ferrous oxide at all. The sulphate of iron was not added, he said, to act as a precipitating agent, namely, to combine with the organic matter and then go down as an insoluble precipitate. His explanation, which, having regard to the quantity added, was a remarkable one, was this: "The salt, known as protosulphate of iron, or more generally as 'green vitriol,' affords the ferrous hydrate. This is rapidly converted into the ferric hydrate, by combination with the oxygen dissolved in the water. In this condition it has the remarkable power of parting with the oxygen thus taken up, and of giving it to the sewage matters. Having thus been reduced to the ferrous state, it is again ready to combine with fresh atmospheric oxygen, which it again yields up to the sewage, and, acting as a carrier of the oxygen dissolved in the sewage liquid, becomes an agent for oxidizing the more readily attacked foul matters, within the limits of the quantity

used." Had Mr. Dibdin tried whether, if ½ grain of ferrous oxide Dr. Tidy. was added to a gallon of ordinary sewage, such an action as he described would actually occur? Had Mr. Dibdin any definite proof further that, after the ferric oxide had been formed, it would deliver up its oxygen to the organic matter and become reduced to protoxide again, if present in the proportion of ½ grain of iron oxide per gallon of sewage? Dr. Tidy had tried it, and he left Mr. Dibdin to fight the matter out. Supposing the $Fe\,O$ to be an active sewage precipitant, $Fe_2\,O_3$, the peroxide of iron, was certainly not active. It was quite clear, with regard to the peroxide of iron, that it was not a precipitating agent at all. The statement as to the permanganate business was a most extraordinary story. There was organic matter in the sewage on the one hand, and ferrous oxide on the other. The permanganate was put in; the ferrous oxide had to select between the organic matter and the permanganate. He knew perfectly well that the very first thing that the ferrous oxide would do would be to take the oxygen from the permanganate, and disregard the organic matter. Ferrous oxide was a thing admittedly easily oxidized; it was not so easy to get the oxygen out of ferric oxide. He questioned altogether the extraordinary value attached to this 1 grain of iron sulphate and 3·7 grains of lime. To show that he was not carrying his view of the action of this small quantity of lime and iron salt too far, he would quote a passage from Dr. Dupré's evidence, given before Mr. J. T. Harrison on an Inquiry respecting the Lower Thames Valley Main Sewerage in February 1884. He was asked by Mr. Michael, "Kindly tell us what you understand to be the process which is to be adopted here? *A.* I understand that the sewage itself is all to be treated with a certain proportion of lime.—*Q.* What do you understand further? *A.* Then there is to be added a quantity of lime, not quite 5 grains per gallon, as I understand.—*Q.* Take it from me that there will be a sufficient quantity of lime for the process; do not tie yourself to 5 grains? *A.* It may be sufficient for your process, but in the process you will get a very bad effluent. —*Q.* What do you suppose is to be done next? *A.* After that it is to be run into a solution of alum in certain proportions. I have taken the proportions from your evidence, but I do not know whether it is right.—*Q.* Take it in any way you please, what then? *A.* There is to be some sulphate of iron, and then it is to be allowed a rest of three hours, then it is to be siphoned or drawn off.—*Q.* We will suppose that it is drawn off. What do you say will be the result? *A.* The result will be, I have very little doubt, a very bad effluent." Then in another place he gave this

Dr. Tidy. evidence:—"*Q.* I am asking you, for the moment, to estimate it at its best? *A.* I think, as far as I understand the process here proposed, it will not produce a good effluent, because the amount of chemicals proposed to be used is much too small.—*Q.* Do you say they ought to be more? *A.* Much more.—*Q.* Would double be enough? *A.* No, double would not be enough.—*Q.* Would three times be enough? *A.* Three times might probably be enough." He would now ask the members to look at Mr. Dibdin's Table, Appendix I, which he himself had studied hard, to see whether the action of this grain of iron was so mysteriously wonderful as had been suggested. The Table represented the "Percentage reduction of oxidizable organic matter in solution by various methods of chemical precipitation." He thought that was a rather bad way of stating the facts, because many persons would have different opinions about the estimation of oxidizable matter. He doubted whether he himself should agree with Mr. Dibdin as to the way in which he had estimated it; indeed, he knew that he should not. The Table was a remarkable one. It was singular to find all the high numbers in the first row. It seemed as if Mr. Dibdin had taken a great deal of care and worked very hard in the first row, and had got good results; for in the last row all the bad results seemed to come in. The first column showed the amount of reduction of organic matter by 3·7 grains of lime. The average reduction was stated to be 11 per cent.; in other words 2·97 per cent. of oxidizable organic matter removed for each grain of lime added. Next came the enormous power of this sulphate of iron. Column 7 showed 3·7 grains of lime and 1 grain of sulphate of iron to have been used, and what was the result? The reduction of organic matter with the 3·7 grains of lime alone was 11 per cent.; with 1 grain of sulphate of iron in addition it proved to be 13 per cent. In other words, whereas each grain of lime had effected a reduction equal to 2·97 per cent. of organic matter, the addition of 1 grain of sulphate of iron had only produced a further reduction of 2 per cent. To show that this was not mere accident, he would take the second column. By adding 5 grains of lime a reduction of the organic matter was obtained amounting to 15 per cent., in other words equal to 3 per cent. for each grain of lime added. In column 10, 5 grains of lime were added and 2 grains of sulphate of iron per gallon, the reduction being now 18 per cent., or a reduction of 1½ grain only of organic matter per grain of sulphate of iron—very much less than the reduction effected by the lime. Again in column 11, 4 grains of sulphate of iron were added, and Mr. Dibdin in this case only obtained 1 per

cent. reduction of organic matter by the addition of 2 grains of sulphate of iron, equal to ½ grain reduction for 1 grain of sulphate of iron. Had iron, then, proved so wonderfully successful? Undoubtedly no. How about the question of cost? Mr. Dibdin had put down the lime at £1 per ton. Dr. Tidy had taken considerable trouble to ascertain what lime would cost delivered at Crossness. He was informed on the highest authority that lime could be delivered at Crossness and Barking for 12*s*. per ton. Then as to the results of this curious mixture of 3·7 grains of lime and 1 grain of iron sulphate. He had examined some of the samples of the effluent produced by the process of Mr. Dibdin and Dr. Dupré. In the first instance when he sent for them, the Metropolitan Board of Works would not let him have them, but owing to the courtesy of Mr. Dibdin he obtained some samples which he had carefully tested, comparing them with samples of average sewage flowing in the London sewers on the day in question. He was indebted to the courtesy of Mr. W. Haywood, M. Inst. C.E., for the opportunity of making the comparison. He would not at that moment give the numbers, which he would preserve to produce on another occasion; he would simply say that the sewage after treatment by the process in question was as foul as the sewage in the Fleet Sewer. Mr. Dibdin evidently foresaw this difficulty—he foresaw that someone would come forward and say that the samples of sewage treated by his process were filthy in the extreme. There was accordingly a remarkable passage in his Paper which he could only describe as a burst of apologetic eloquence. "Long and disastrous experience has now taught the public that, in the case of drinking-water, nothing is more deceptive than appearances, that often the most cooling, sparkling draught contains the elements of death. Numbers upon numbers of self-sufficient people have succumbed, after having seen their dear ones carried off before them. Who cannot now recall instance upon instance of over-confidence in some long-used source of the daily water-supply, and equal want of confidence in the advice of medical men, resulting in that stern lesson which none can unlearn? If this is so with water, how much more does the case apply to sewage? Hold up a glass of clear liquid poison, declare it to be pure, and thousands will believe the statement; but hold up a glass of pure water with but a small fraction of clean ferruginous clay diffused in it, declare it to be harmless, and how many will turn away with a smile of incredulity? These cases, extreme as they may appear to be, illustrate only too well what may, and indeed what often does, happen, in refer-

Dr. Tidy.

Dr. Tidy. ence to sewage effluents, and demonstrate that clearness is no more a sign of purity than is turbidity a sign of foulness." What did that passage mean? If it meant anything it meant, "Take up a glass of sparkling water from many of our wells—things are not what they seem—that sparkling draught contains the elements of death likely at any moment to carry off the dear ones at home. Hold up a glass of my sewage effluent. True, it may smell abominably; true, it may actually be as bad to all appearance as the sewage running in the sewers. Do not believe it; it is as pure as salutaris water." He had spoken warmly on the subject because he felt warmly. He was quite certain that the system upon which thousands of the ratepayers' money was to be wasted would and must prove a failure. As to the treatment of London sewage, there was no real difficulty in it at all; but let not those men be asked to remedy an evil which they had said did not exist. The only difficulty was that the Metropolitan Board of Works had committed itself hopelessly, and did not now like to admit that it had been in the wrong. Its policy, to his mind, had for years past in most matters been one long continuance of muddling inactivity. Before long the authorities would be called upon to account for the course they had taken in the matter of the London sewage, and he felt convinced that the Metropolitan Board of Works had with its own hands, and with its own sewage, written "Ichabod" on the doors of Spring Gardens.

Dr. Dupré. Dr. A. Dupré observed that error died hard, and it was a mischievous error that had been propagated that sewage could be made to pay the community. It had done more to retard the proper treatment of sewage than anything else. He came to England thirty years ago full of the theoretical notions inculcated by Liebig, who then compared England to a vampire sitting on the breast of Europe sucking out its life-blood, and discharging it through its sewers into the sea. He had since become a sadder, and, he hoped, a wiser man, and had come to the conclusion, which he thought most people had reached, that sewage was a nuisance to be got rid of, irrespective of expense or any idea of making a profit out of it. Liebig himself in after years came to the conclusion that there was something in the sewage system adopted by England which rendered it impossible to make it of any agricultural use. There was no doubt a great deal of valuable material in sewage, but the difficulty was how to get at it. Many rivers in Europe carried gold, but if a man could earn a penny a day on something else it would not pay him to get gold out of a river. He had calculated that the silver in the sea-water that passed by Southend every year

would be worth £36,500,000. All the gold in California and Australia was as nothing compared with the unlimited stream of silver that passed the coast. But who ever dreamt of getting silver out of sea-water? It did not pay. In like manner Englishmen had adopted for good or evil—he sometimes thought for evil—the water-carriage of sewage, which probably would not be altered in the lifetime of any one present; and the idea, therefore, of making sewage pay must be given up. He did not say that there might not be some places where the sewage might be made to pay, but in the great majority of cases it was mere folly to think of making money out of it. Lieut.-Colonel Jones had raised a laugh against him in regard to his suggestion about treating sewage with organisms. He had, however, conclusively proved that by taking London sewage, or any sewage either by itself, or added to river-water, and sterilizing so as to kill life, no change took place, and it could be kept for weeks without the slightest alteration. By adding some organisms the organic matter in the sewage disappeared rapidly. For years a discussion had been carried on between Dr. Tidy and Dr. Frankland. Dr. Tidy had stated, "Add sewage to river-water, there being 20 volumes of water and 1 volume of sewage; watch it, and you will see that although it comes in a foul black stream it alters almost yard by yard, and in a short time it disappears." And his idea was that it disappeared by direct oxidation. Dr. Frankland, on the other hand, contended that no river in England was long enough to produce that result. Both were right, and both were wrong. Both forgot, or did not realize, that the action was due to organisms in the water. The whole question was one of a sufficiency of these organisms. With a sufficient number of organisms in the polluted water, and plenty of air, the sewage could be dealt with in the easiest and most perfect manner. If the aeration of rivers could be kept to a proper point, say 30 or 40 per cent., no nuisance need be feared from sewage. The organisms to which he referred might be sneered at, but they were among the most powerful agents in the world. With regard to Dr. Tidy's quotations from evidence given by him, he could only say that he would now repeat the same evidence without the slightest alteration, except in one point in which he was mistaken. Any one who had had experience in sewage-treatment knew that the rate at which the precipitate subsided varied considerably with the nature of the sewage, it varied apparently also with the bulk treated. Unfortunately he had been experimenting at the time with sewage that required a longer treatment than many others. He had however lived

Dr. Dupré.

Dr. Dupré. and learned, and he now admitted that, as a rule, the time for precipitation need not be longer than four hours. As to the effluent produced, he held that any chemist or scientific man, who was consulted by an authority or a private individual, was bound to give the best advice of which he was capable. He was not bound, because he happened to have some hobby, to run his clients into an expense of hundreds of thousands of pounds, when he believed that all the necessary result might be obtained with a much smaller outlay. It would, he hoped, be clear to every one that the character of the sewage effluent must depend upon the place where it had to be discharged. What might be a nuisance in one room in a house might be no nuisance in another; what might be a nuisance in the dining-room would be no nuisance in the stable. The sewage effluent to which his evidence related was to be discharged near Kew Gardens, into a part of the river which was so shallow that it could occasionally be crossed on foot, and where it was a pleasure resort for Londoners, where thousands of pleasure-boats passed every year, not to say every week, and these would have been obliged to go through the sewage-effluent itself. Was that not a place where the sewage effluent ought to be something specially good? No man in his senses would recommend a sewage effluent, treated by 3 grains of lime and 1 grain of sulphate of iron, to be discharged into a part of the river, where he might have to take his pleasure-boat through the sewage-stream itself. Dr. Tidy moreover omitted to mention that the effluent to be discharged at Crossness would, whenever necessary, be deodorized by manganate of soda and sulphuric acid; the effluent near Kew was not deodorized. This effluent was to be produced by a certain amount of lime, iron, and alumina. At the very time when Dr. Tidy gave his evidence before the Committee of the House of Commons, stating that the sewage-effluent would be purer than the river in which it was to be discharged near Kew, Dr. Dupré obtained some samples of effluent produced by exactly the same process, and it was as foul, probably, as the sewage in the Fleet Sewer was on the day when Dr. Tidy examined it for the purpose of comparison, except that it contained little or no suspended matter. This was the second time he had, in the presence of Dr. Tidy, explained the apparent discrepancy between his evidence and his recommendation, he hoped he should not have to do it a third time. He now came to the essential question of sewage-precipitation. According to his experience, it mattered very little what precipitants were used. As Mr. Dibdin had pointed out, a more or less

clear effluent might be obtained; but fairly examining the amount of organic matter remaining in the solution, it mattered very little whether 50 or 10 grains of lime were added, or whether alumina or iron was added or not. The essential effect was that matters in suspension were precipitated. One point mentioned in Mr. Dibdin's Paper might to some extent reconcile conflicting statements, the fact that the stronger the sewage the greater the proportionate amount of organic matter that could be removed. In London the sewage to be dealt with was certainly somewhat diluted, and whether much or little precipitant was used within practical limits, it had very little effect upon the effluent. He wished to speak with the highest respect of the Royal Commission, and any one finding that the conclusions arrived at by such a Commission confirmed his own might well be pleased at such a result; but a dozen Royal Commissions would not make him alter his own convictions if he had arrived at them from a fair study of the subject. When he gave his evidence before that Commission there was little or no nuisance in the river, and although hundreds of persons were before the Commission, no instance was given in which any injurious effect had been produced by the pollution of the river, by any one who had visited it. He had suggested that if the Metropolitan Board of Works would organize a series of excursions down the river, so as to let the public see the actual state of things, he was quite sure that the outcry then raised by persons, who wished to treat the sewage, would have been overwhelmed by the outcry of the public at the idea of spending millions for removing so small a nuisance as had existed before 1883. Since then there had been two remarkably dry and warm summers, when no doubt the river was not in a condition in which it ought to be, at any rate for a short time in the year. That was a new experience, and of course any reasonable man would learn by experience, and he was now ready to admit that something must be done to purify the river. The question was what was to be done? It must be enough to remedy the evil complained of, but no more. It was easy for the Metropolitan Board of Works, or those who advised it, to recommend schemes at an expense of hundreds of thousands or millions; the expense did not come out of the pockets of the Metropolitan Board of Works nor of those who advised it, but if 3·7 grains of lime and 1 grain of sulphate of iron, supplemented when necessary by deodorization, sufficed, what was the use of adding more? When Mr. Sillar was speaking of spending £100,000 in experiments, Dr. Dupré felt tempted to ask him how much of that money came out of the pockets of the ratepayers, where the Dr. Dupré.

Dr. Dupré. A B C process had been tried and had failed. With regard to Dr. Tidy and this A B C process, he possessed a report signed by Dr. Tidy and Professor Dewar, two very able men, who knew perfectly well what they were about, and he deliberately said that that report, dated April 1885, was not worth the paper on which it was written. Here was a Paper dealing with the A B C process, which somehow or other always cropped up when Dr. Tidy spoke about sewage. He had read the Paper and endeavoured to get some information from it, but notwithstanding every effort he had failed to grasp its meaning. A series of experiments had been devised for the purpose of finding out how much organic matter in solution the A B C process removed, and he found that the effluent, after treatment, on an average contained a little more organic matter than it did before. In an answer given at the Society of Arts,[1] Professor Dewar stated, and, he admitted, stated fairly, that part of that was appearance—that they had added so much salts to the sewage that what was put down as organic matter was really water. But he asked any reasonable man what was the value of a Paper which was prepared for the purpose of settling a given question, and which after settling the point had to explain it away. Either there was more organic matter in the effluent or there was not; or the whole series of experiments was not worth the time it had occupied. He had tried to find out how much of the A B C mixture was used. For as every grain per gallon added to the London sewage was equal to 10 tons a day, when 50 or 100 grains were added it became a serious matter. The average cost per ton would be £1 to £2, or more. The only statement that he had found was, that in one series the precipitating-agent used was not much more than one-third of the total sludge obtained. He should have thought that a chemist would at least say it was not much more than one-half of the amount of suspended matter in the sewage. It was perhaps thought better to put it down at one-third the total sludge. Whether that total sludge was dry or not he did not know. In the other case, the third series, they reported that the relation between sludge and precipitant was not quite so favourable; the total amount of sludge obtained being less than in the former case, owing to the small amount of sewage. In the second series, the amount of sewage was something like 540,000 gallons with 59·9 grains of suspended matter per gallon; the total amount would therefore be 32,000,000 grains. That was the sludge where the precipitant was not much more than one-third. In the case which

[1] Journal of the Society of Arts, vol. xxxiv. p. 670.

was supposed not to be quite so favourable, the total amount of sludge produced being less than the other, the amount of sewage was 358,000 gallons, with as much as 234 grains of suspended matter per gallon, the total suspended matter being 84,000,000 grains. Yet they asserted that the effluent was always almost absolutely clear. What became of the 50,000,000 grains that disappeared in the process? Lastly, Mr. Sillar had stated that the A B C works were placed in the hands of Professor Dewar and Dr. Tidy for three months. Their record was for three days, a little over 3 per cent. He should very much like to see the remaining 97 per cent. He had not provided himself with extracts from the evidence, but he believed that Dr. Tidy stated before the Royal Commission that an effluent might be produced at Crossness, and be discharged into the river at any state of the tide. The Metropolitan Board of Works was now undertaking to build tanks for precipitating. The Board was not at all wedded to the particular process that had been mentioned, and whether the A B C process, or iron, or alumina, were used, the tanks were as ready for the one as for the other. Meanwhile, however, the process to be adopted was far the cheapest that had been recommended, and the Metropolis would be saved such a sum every year as that, supposing it to be necessary some years hence to make an alteration, the ratepayers would in the meantime have saved more than the outlay that might then be necessary. Dr. Dupré.

Dr. Tidy desired to say that neither directly nor indirectly were Professor Dewar or he in any way concerned with the Native Guano Company. Dr. Tidy.

Mr. H. Maudslay said that the general tendency of the discussion had been rather to find fault in regard to the chemistry of the question, than to deal with the subject of sludge and its disposal. He desired to say a few words on the latter subject, because he thought that a material had been discovered which had produced a very good and marked result, namely, porous carbon, which he believed to be a lignite, and he had been informed that there was a large field of it at Bovey Tracey and Newton Abbott. It was that material mixed in certain proportions which had produced so favourable a result at Southampton, where all the sludge had been disposed of at a small advantage, which was certainly much better than throwing it into the sea. Certain combinations of the material had the effect of deodorizing and purifying the effluent of sewage to such an extent, that he and others had drunk the water proceeding from it. He wished to refer to the results of the dredging of a portion of Malta Harbour. Mr. Maudslay.

Mr. Maudslay. The material dredged out came from salt water, and the authorities being afraid that it might produce a very bad result, adopted the plan suggested in Mr. Dibdin's Paper, namely, that of taking the material out in barges to a certain distance and emptying it into the sea. The plan, which might be supposed to be very ingenious, succeeded so far; the flotation of the barges was sufficient, the speed attained was satisfactory, and the result was what the engineers who carried out the scheme determined that it should be. The process was therefore considered a success, but there was a loss of the sludge which would have been beneficial to vegetation in an island composed of rock. If it had been left in certain cavities upon the surface of the ground, the salt would, by the action of the rain and sun, have been deposited and the sludge probably purified to such an extent as to make it useful on the island. A century or so before, the authorities on the island had paid for earth to be brought from Sicily for the purpose of supporting vegetation upon the island. The island wanted earth, manure, and material for increased vegetation, and yet the very thing that it wanted was thrown into the sea. With a natural chemical agent which would produce the desired effect in purifying sewage, as there now was in porous carbon, surely it might as well be used for that purpose, instead of throwing the London sludge into the sea as if it were valueless. If those who had the power would only try it for London, they would probably obtain the same beneficial result as had been obtained at Southampton. There was a large area in Devonshire in which the material was found; there was a railway within a very short distance of it, by which it was taken away in bags to Southampton. The sludge could be utilized by any machine that might be preferred by the engineer having charge of the works. At Southampton the sludge was not offensive.

Mr. Strachan. Mr. G. R. STRACHAN stated that he had been at Southampton, and had seen the process adopted there in its every-day work. It was misleading to members to state that all the sludge made at Southampton was sold, because out of a population of sixty-three thousand, the sewage of only fourteen thousand persons was treated. Southampton was so situated that it could get for its rough dust 1*s.* 6*d.* a load, whereas in London 9*d.*, 1*s.*, and in some cases 2*s.* 3*d.*, had to be paid to get rid of it. When the sludge was mixed with the dust, horse-droppings from the streets, and all the other manure obtainable from the town, it was saleable. From what he saw, he did not think that the sludge from the porous-carbon process was either better or worse than sludge from any

other process that was efficient. It had, moreover, the smell of ordinary sludge. He had been at Southampton on a cold day, and the sludge then certainly had that smell distinctly. It had been stated that burning the sludge was a good method of getting rid of it, and that a good mode of burning it was to utilize the dust for that purpose. At Chelsea, where the dust was purely domestic, it being insisted that all trade refuse should be kept out of it, last year he kept accurate records of the quantity, and it might be taken from him that 4 cwt. of dust per year in London was given by each inhabitant. It was stated in Mr. Crimp's Paper, that in an efficient chemical process, 10 cwt. per head per year of wet sludge containing 90 per cent. of moisture was obtained, so that 2 cwt. of dried sludge would contain 50 per cent. of moisture. He would ask those gentlemen who said that the dust of a town was sufficient to burn the sludge of the town, whether they seriously asserted that 4 cwt. of dust was sufficient to burn 2 cwt. of sludge, when one-half of that sludge was water? He should be glad if Mr. Jones, of Ealing, would state the exact quantity of sewage treated there chemically, the quantity of sludge, wet or dry, that he obtained from the sewage works, and the quantity of dust; and whether he did, as a matter of fact, burn all the sludge that came from his process? If that could be done at Ealing, it could be done elsewhere. No general statement that it was done at Ealing or at Southampton ought to be sufficient, but the exact facts of the case should be stated. Mr. Strachan.

Mr. Charles Jones said it was not necessary to discuss the quantity of dust. He would simply state that he dealt with the sludge of a population of twenty thousand persons. It was not necessary that he should use dust. He had burnt tons of sludge pure and simple without the admixture of dust. Sludge consisted almost entirely of carbonaceous material. The question had been a burning one with him for many years. The experiments of the late General Scott were carried out by him, and his experiments with sewage-cement arose from the experiments which Mr. Jones was making. When the Association of Municipal and Sanitary Engineers, of which he was the Honorary Secretary, met at Leeds, in 1880, he saw for the first time the destructor in full work, and he there recognized the fact that it could deal not only with the house-refuse difficulty, but also with the sludge difficulty; in the next season he obtained from his Board permission to erect a four-cell destructor, and from that time the whole thing had been a success. He had been asked whether he burnt all the sludge? He would only reply that if a farmer Mr. Jones.

Mr. Jones. wanted 50 tons of sludge he was at liberty to take it. What he did actually burn was the sludge of twenty thousand persons. He believed, however, that the refuse from the houses was sufficient to burn the material of the sewage-sludge which came in contact with the works of any one town. In 1884, seeing a notice in the papers, that the Metropolitan Board of Works was going to try to burn sludge, he wrote to the Chairman, and recommended him, instead of carrying out the experiment with a kiln that was not efficient, to go to Ealing, and see what was being done there as a matter of every-day work. He had heard that an attempt had been made in this direction, but did not succeed. The works at Ealing were open to all who chose to visit them when they were in operation. When there was no material to burn, the fires were sometimes banked up for a week, and then of course it would be useless to visit the place. In the last report of the Metropolitan Board of Works, p. 8, after referring to the suggestions of the Commission in reference to the various modes of dealing with sludge, it was stated: "The process of burning the pressed sludge has been tried in various ways, and the conclusion arrived at is, that whilst this method of disposing of the material presents little difficulty, the expense of carrying it on without nuisance would be so great as to be prohibitory." That statement was entirely fallacious, because there was not the slightest necessity for any nuisance. The gases thrown off were highly combustible. He burned the gases from the sewage of twenty thousand persons at a cost of 1*s*. 6*d*. per day. He procured breeze from the gas-works close at hand, for which he paid 1*s*. 6*d*. per chaldron. He used a muffle-furnace for the destruction of the gases, all the gases and smoke passing through it, and in this furnace, or fume cremator, as it was called, he used about a chaldron a day. The actual cost, however, was practically less than nothing. With the destructor he formerly got a pressure of 20 lbs. per square inch of steam using the destructor with a boiler attached for precipitating, pumping, and so on; but now he obtained a pressure of 40 lbs., so that he gained 20 lbs. by the combustion of the gases, and the small amount of breeze used in the cremator, and there was no smell whatever. The furnace stood in the midst of a suburban district. When he first used the destructor there was some smell, but since the gases had been burnt at this small expense he was able to get rid of all the sludge without difficulty. Formerly farmers used to snap their fingers at him when he had 500 or 600 tons that he could not get rid of, and one winter it had cost him between £300 and £400 to remove it. That had

put him upon his mettle, and now he was able to destroy the sludge without difficulty. Sewage-sludge was a thing to be got rid of. It would never do as a money-making material, except upon the Stock Exchange. He ought not, however, to omit stating that he got back 25 per cent. of the sludge in the form of a very hard clinker, which was valuable to grind for sand, for concrete, for wall-making, and it was also useful as a substitute for York stone. He was now laying it down in the district; it was quite equal to any Victoria stone, and at a cost of only 3*s.* per superficial yard. Mr. Jones.

Mr. JAMES MANSERGH, while he dissented from the deprecia- Mr. Mansergh. tory remarks of Lieut.-Colonel Jones on Mr. Dibdin's Paper, quite agreed with his commendation of the Paper of Mr. Crimp, and of his work at Wimbledon. He had witnessed personally the very thoughtful and careful manner in which Mr. Crimp had dealt with the sewage at Wimbledon since it had been under his charge. He had, in fact, brought what used to be a ghastly failure, ending in serious litigation, to a conspicuous success, and he deserved great credit for it. Mr. Crimp's remarks on the construction and working of filter-presses showed that he had taken great pains to utilize the machine to the fullest possible extent, and in the most economical manner. Where the effluent was to be passed over land, it might suffice to run the liquid expressed from the sludge back to the tanks for a second treatment, as was done at Wimbledon; but his experience led him to believe that, where land was not available, this liquid would probably need special treatment in another way. The details of cost of working the presses, and the experiments on the manurial value of the sludge-cake as compared with farmyard manure and superphosphate, were most useful, and it was to be hoped Mr. Crimp would continue to accumulate such facts and communicate them, whether they turned out in the future to corroborate his present opinions or not. The use of filter-presses had undoubtedly diminished the trouble in dealing with sewage in many inland towns. The accumulation of unpressed sludge had for years been the great incubus of many sewage-works; it had now happily been got rid of at Wimbledon. At Chiswick, also, which a short time ago was in litigation, presses had been erected under Mr. Strachan's advice, and he had been informed by the Surveyor that the stuff was now readily taken by the market-gardeners, who grew considerable crops by its aid. At Coventry 4,000 or 5,000 tons a year were disposed of, and 1*s.* a ton was received for it, with the exception of a small quantity that was handed over to the Corporation

Mr. Mansergh. tenants. So far the use of sewage-presses had no doubt been a great advantage. He would now make a few remarks on Mr. Dibdin's Paper. Mr. Dibdin had stated (p. 156) that it would be desirable that the sewage should be deodorized on its way from the houses into the main sewers. There were one or two kinds of apparatus by which that had been done fairly successfully, and in many houses of a good class it might be possible, but to expect it to be done universally was quite out of the question. The Metropolitan Board during last summer had erected sheds at the heads of many of the principal sewers, from which he believed there had been passed a quantity of manganate of soda into the sewers, with a view of deodorizing their contents on their way to the outfall. If not premature it would be very interesting if Mr. Dibdin could give some information as to the results of those experiments. If deodorization at the very earliest stage could be thus effected, no doubt the advantages pointed out by Mr. Dibdin would be obtained, and a trouble constantly pressing upon local authorities and their officers would be mitigated, that was, the offence produced under certain conditions by surface ventilators. This was a growing difficulty, in consequence of changes taking place in other directions. These changes were: first the making of watertight sewers and the diminution of the water let in from wet subsoil; and secondly, the isolation of house-drains from the mains by intercepting chambers, and the consequent loss of numbers of more or less effective ventilators. Mr. Dibdin had raised the question of the superiority of iron to alumina as a precipitating agent, and he hoped that the chemists would thrash out this point before the end of the discussion. Alumina had always been regarded as one of the sheet-anchors of precipitation-methods. Mr. Dibdin had also raised the question of nitrification. Mr. Mansergh agreed with Dr. Dupré that it was hardly justifiable to ridicule his remarks upon that point. Five years ago Dr. Tidy, in a discussion on Mr. Folkard's Paper, raised a laugh by asking, in his inimitable manner, Where were the germs?[1] Since that time germs had come to the front very much indeed; and in connection with the examination of the London waters, Dr. Tidy was now well immersed in bacteriological research. At Burton-on-Trent, where he was now dealing with the sewage of the town on a farm of 500 acres, some interesting experiments were being made, with a view of obtaining nitrification, which, under the circumstances of the soil and the sewage, was a very difficult thing to accomplish. With the

[1] Minutes of Proceedings Inst. C.E. vol. lxviii. p. 79.

Mr. Mansergh.

assistance of Dr. Ashby, of Grantham, and Mr. Arthur Marshall, Assoc. M. Inst. C.E., who were working enthusiastically on the experiments, he had been encouraging the growth of those micro-organisms. These creatures disliked very much to "stew in their own juice." In carrying on their function, they manufactured nitric acid, but they could not live and continue to do their work in it; they had, therefore, to be supplied with a base, and this was being given them by putting upon the land a certain quantity of carbonate of lime. They had made experiments on a small scale, and were now dealing with a plot of 8 acres, from which they could collect the effluent for analysis, and the results had been, so far, encouraging. Nitrification had been started and nuisance diminished. He agreed with Mr. Dibdin that the anti-septic treatment of sewage was a mistake. At Carlisle, where Mr. McKie and he had carried out the first sewage-farm in England twenty-seven years ago, carbolic acid had been introduced into the sewage, which was, no doubt, an undesirable thing to do. Mr. Sillar's earnest and energetic speeches on the A B C process were always interesting, but he thought it was high time that the mystery of that system should be in some way cleared up. The Native Guano Company could, no doubt, and did produce an exceedingly good effluent, but it had been always astonishing to him that while it had had the chance of making experiments at Leeds, Leamington, Hastings, Crossness, and other places, a capital of £200,000 invested, valued at one time on the Stock Exchange at £1,000,000, it had now in 1887 only Aylesbury to show. The Company had always contended that it made a manure readily saleable at £3 10*s.* per ton, with a profit of £2 a ton. Surely, if that were really the case, every town in England would be adopting the process. Mr. Sillar had pointed out that the value of the A B C sludge was due to the fact that no lime was used in the process. Was this the true explanation of the apparent enormous difference in value between this sludge and other sludges? It was high time the mystery was cleared up. The report of Professor Dewar and Dr. Tidy did not appear to explain it. If the pretensions of the A B C Company could be substantiated, it had undoubtedly been hardly dealt with in the past, and deserved, for its dogged perseverance, greater success in the future. Mr. Mansergh had some years ago made, on behalf of a sanitary authority, what he considered a businesslike proposal to this company, which, if its assurances were reliable, would have resulted in a profitable undertaking being entrusted to it, with the chance of others to follow; but it had been rejected, and this had prevented him

Mr. Mansergh. making further approaches. He had no prejudice whatever against either the company or the process, and would like very much to be satisfied on this crucial question of the intrinsic value of the manure. With regard to the very entertaining speech of Dr. Tidy, it ought to be clearly understood that the learned Doctor did not object to the system which the Metropolitan Board was intending to carry out at the two outfalls. Dr. Tidy agreed with the idea that the sewage should not be taken further down the river; but should be treated at Barking and Crossness. The whole of his objection, as he understood, was to the intended use of 3·7 grains of lime and a single grain of iron to a gallon. If 20 grains of lime were used, as suggested in Dr. Tidy's evidence before Lord Bramwell's Commission, the impending doom of the Metropolitan Board might possibly be delayed. No doubt, to any one experienced in the chemical treatment of sewage, these figures of Mr. Dibdin's were startling figures, and if he proved, in actual working on a large scale at Barking, that he could produce a sufficiently good effluent with these quantities he would deserve infinite credit. With regard to the decision of the Metropolitan Board as to the treatment of the London sewage, he would say that it met with his approval, in principle certainly. During the preparation of the evidence for the arbitration between the Metropolitan Board and the Thames Conservators, known as the "Mud Case," and for the inquiry by Lord Bramwell's Commission, he had frequently gone down the river, and he was bound to say that he never noticed any serious nuisance at either of the outfalls. Strangers might go there for years without knowing that sewage was being discharged at those points. In such years, however, as 1884, when in a hot summer very little land-water was coming over Teddington weir, and when the temperature of the water near the outfalls became abnormally high, the state of things was enormously changed. Then the putrescible mud accumulated on the submerged banks by deposition from the untreated sewage was floated up to the surface, by the evolution of gases, in great patches, and was there broken up by the winds, currents, and traffic, until the river became a black foul-smelling stream throughout a length of several miles above and below the outfalls. Such a state of things showed that the original intentions of the Metropolitan Board, as submitted to Parliament thirty years ago, ought to have been carried into effect; that was to say, the suspended solids ought from the first to have been removed prior to the discharge of the sewage into the river. If this had been done, in his opinion neither the great mud fight nor Lord Bramwell's inquiry would

Mr. Mansergh. ever have taken place. And now, if the Board would take out the solids by some effective precipitation process, the sewage might, he believed, be discharged harmlessly at Barking and Crossness at any state of the tide. As to the disposal of the sludge, the Metropolitan Board was, he thought, carrying out pretty closely the suggestions of the Royal Commission. It might seem a clumsy mode to take all this material down by steamer 10 miles out to sea; but it would be most difficult to treat it anywhere nearer. Of course, it would seem more desirable to an engineer, if it had to be taken to sea, that it should go in some pipe or conduit; but he believed it would be difficult to find any place upon the coast where untreated sewage could be discharged, and where it would be at all times carried away by the currents without doing harm by creating a nuisance. If it were taken 10 miles out to sea, the fishes would certainly dispose of it most effectually. Although he was in no sense the apologist of the Metropolitan Board, he agreed with Mr. Dibdin that the principle of its present proceedings (without expressing any opinion on the details) was in accord with the suggestions of the recent Commission. In their 3rd conclusion, the Royal Commissioners said:—"We are of opinion that some process of deposition or precipitation should be used, to separate the solid from the liquid portions of the sewage." In the 4th, "Such a process may be conveniently and speedily applied at the two present main outfalls." In the 5th, "The solid matter deposited as sludge can be applied to the raising of low-lying lands, or burned, or dug into land, or carried away to sea." So far the Metropolitan Board appeared to be carrying out those suggestions. The Commissioners went on to say, in No. 7, "The liquid portions of the sewage remaining after the precipitation of the solids, may, as a preliminary and temporary measure, be suffered to escape into the river." In conclusion, No. 10, they said: "But we believe that the liquid so separated would not be sufficiently free from noxious matters to allow of its being discharged at the present outfalls as a permanent measure. It would require further purification, and this, according to the present state of knowledge, can only be done effectually by its application to land." The exact meaning of this conclusion was not easy to make out. It appeared to be incomplete without some reference to time, or to population, or increasing quantity of sewage, and seemed to have been added as a sort of saving clause out of excess of caution. In that respect also, the Metropolitan Board was carrying out the suggestions of the Commission.

Mr. Birch. Mr. R. W. Peregrine Birch knew that Dr. Tidy had disputed

Mr. Birch. some of the conclusions arrived at by Mr. Dibdin, but it should be borne in mind that the information, given by Mr. Dibdin to the Metropolitan Board of Works, had been supported by Sir Frederick Abel, Dr. Odling, Dr. Dupré, and Professor Williamson. Although he was not prepared to admit that precipitation was either the right thing or the cheapest that the Metropolitan Board could undertake, he wanted to learn all he could about precipitation, and he welcomed the information given by Mr. Dibdin on precipitation and the relative merits of precipitation processes. Mr. Birch then exhibited in a diagrammatic form the results given by Mr. Dibdin in Appendix I to his Paper. The lesson which, he thought, was to be gained from the diagram and from Mr. Dibdin's Paper generally, was, that there was more difference between the sensitiveness of two sewages, even two London sewages, to any chemical treatment whatever, than there was between the effect of one chemical treatment and of another upon any specimen of sewage, although the different treatments might vary in cost from £13,000 to £9,000,000 a year. It would be seen that while samples 20 and 21 only yielded an average of 10 per cent. to all the twenty-four different treatments, and sample 6 yielded as much as 36 per cent. on an average to each of the twenty-four treatments, no such difference was to be found between the average effect of any two treatments upon all the samples. The results were not due to any chance or any mistake in the analysis. Looking, for example, at sample 6, it would be seen that it had yielded liberally to all chemical treatments alike; No. 10 had also yielded constantly to all of them, and sample 1 had been a very good one all the way through. There were, no doubt, exceptions to the rule, and he thought that they were very suggestive; possibly Mr. Dibdin had found the results so varying that he had hesitated to build up any theory from these facts; but notwithstanding, Mr. Birch hoped that he would give all the facts bearing upon the twenty-three samples and their treatment, as to the character of the sewage taken, the age of the sewage, the strength, the temperature, and the time of taking the sample, also how long the sewage was kept before the experiment was made upon it. It was clear from the experiment on the solution of mutton, that the strength of the sewage had some bearing upon the susceptibility to chemical treatment; but the figures showed that there was some much more complex element than the simple strength of the sewage in dissolved matters, for while he increased the strength of the mutton solution from 0·1 per cent. to 20 per cent., or two hundred fold, he only increased

the sensitiveness to chemical treatment from 56 to 90, or some 60 per cent. He would ask whether the twenty-three samples had been previously filtered, or whether they contained at the time of treatment all their suspended matter. If they contained the suspended matter he thought that possibly the amount of it might have affected the action of the chemicals on the dissolved matter. A second diagram which Mr. Birch had prepared from the same Table exhibited the relative effect of different chemicals on the suspended matter, as well as on the dissolved matter. Mr. Dibdin's figures only referred to the dissolved matter; and the comparison between the yielding of the dissolved matter to the various reagents did not give a fair comparison of the merits of the precipitant. While sample 7 yielded 13 per cent. of its dissolved organic matter at a cost of £20,000 a year, and the last sample but one yielded 31 per cent. of dissolved organic matter at a cost of £800,000, both of them would take out practically all the suspended organic matter contained in the sewage; and, if to the amount of dissolved matter taken out were added the 14 grains of suspended matter, which was removed, instead of the two precipitants being in merit as 13 to 31, they would be as 83 to 101, the difference not being worth the cost. Mr. Birch.

Mr. BALDWIN LATHAM could not allow the opportunity to pass without saying a few words upon the two Papers. With reference to the first Paper, it had, he thought, always been a question in dispute how much solid matter London sewage really contained. Ever since the great mud inquiry, the Metropolitan Board of Works had been endeavouring to show that London sewage contained a very small amount of suspended matter, and Mr. Dibdin had pointed out that it only contained 27 grains of such matter per gallon. This was at the rate of 0·1 lb. per head daily, while the suspended matter in ordinary sewage was not less than 3½ oz. per head daily; and taking the results given in Mr. Crimp's Paper, was very much more than this latter amount in the case of Wimbledon. By reference to Sir Joseph Bazalgette's report, and also the report by Mr. Keates, in January, 1873, relative to the experimental operations of the Native Guano Company at Crossness, where upwards of 11,672,000 gallons of sewage were treated, it would be seen that on the south side of London the sewage contained 57½ grains per gallon of suspended matter. It was a notorious fact with reference to the sewage of the south of London that it was more dilute than that in the north. The figures of the Metropolitan Board and of the Royal Commission on Metropolitan Sewage Discharge showed that the Mr. Latham.

Mr. Latham. proportion was 50 on the south and 30 on the north. If, therefore, a few years ago there were 57 grains of suspended matter in the south, he could not conceive how it was that there were only 27 grains in the north. The suspended matter was not at all difficult to deal with; but the proportion of chemicals now proposed to be introduced for the treatment of sewage was certainly a novelty in all places in which such precipitation had been attempted to be carried out. He knew from personal experience that to put 3·7 grains of lime and 1 grain of sulphate of iron into the ordinary sewage of a town, especially a manufacturing town, would have no effect whatever upon it. He could not imagine how it would be possible to produce an effluent fit to discharge into the Thames with such an amount of chemicals. It would be only throwing the chemicals away. After that process the sewage was to be treated occasionally with 1 grain of a material containing a large amount of oxygen, namely, manganate of soda. Accepting the volume given in Mr. Dibdin's Paper, when it was going to be treated at that rate, 10 tons would be applied daily to the sewage. What were the conditions under which the sewage was now discharged into the Thames? On the average, taking 30 cubic feet per minute as the quantity of river-water discharged over Teddington Lock for each square mile in the course of the year, a little over 45½ tons of oxygen were every day poured into the river at its upper end, and the sea-water, on the average of the year, would bring in more oxygen than the upland water as far up as Erith. Now it had been shown that at no period had that oxygen been sufficient to make the river pure, so that fish could live in it. Ever since the Metropolitan sewage had been turned into the river fish-boats came up no higher than Gravesend, being gradually driven down as the sewerage works extended. From the time when the first outfalls were opened it had never been possible to bring live fish to London. For miles the river was devoid of any sign of fish life. In exceedingly low-water periods, as in 1884, to which Mr. Mansergh had referred, the volume of water passing into the river at Teddington was reduced to about 10 cubic feet for each square mile, and at that rate 15 tons of oxygen were poured every day over Teddington Lock; but in such a period a proportionately larger amount of oxygen was brought in with the sea-water which was then in considerable volume in the river. And what was the state of the river? Why, the whole river about Woolwich, and below the outfalls, down to Erith, was one seething mass of putrefied matter. If 40 tons of oxygen were now daily passed into the river in the way men-

Mr. Latham.

tioned, and it did not produce an oxidizing and purifying effect, how was it likely that 10 tons of that particular salt would effect the object? It would be simply waste to spend a large sum of money upon that most expensive salt, and to use it in the proportions mentioned. With reference to the materials which could be employed for precipitating, the list referred to contained nothing like the number which had been introduced from time to time, and with which he himself had personal acquaintance, for the treatment of sewage; in fact, there was hardly an earthy salt which had not been patented and attempted to be used, either by itself or in combination with other earthy salts, for treating sewage. The experiments made by the late Professor Way during the inquiry of the Royal Commission on Metropolitan Sewage Discharge, showed that one of the simplest processes of precipitation had not been tried at all. The river at high water contained an enormous quantity of chloride of magnesium, which was an excellent precipitating agent in conjunction with lime, so that if a little water were let into the tanks at high tide, all that would be needed would be to apply the lime in sufficient quantity, and there would be no necessity for any other precipitating agent. In that way there would be an enormous deposit of sludge, as the magnesium salts produced a much larger deposit and a much more satisfactory effluent than the lime alone. He did not quite agree with Dr. Tidy in his remarks with reference to the iron. Iron was a more expensive salt than lime, and, according to the experiments, it did not remove such a large amount of oxidizable matter; but in all probability iron would remove matters that lime would not. Iron had a power of combining with dissolved organic matter in water which lime did not possess. The particular matter which lime would not act upon iron might, and so produce good results; but in order to get those results larger quantities of iron were necessary than were proposed in this case. At Northampton iron salts were used in the proportion of 4½ grains per gallon to 15 or 16 grains of lime, with the result that the river was as foul after treatment as before. The sewage at the outfall works was made to appear clear, and the river seemed to be inoffensive; but after it had flowed a short distance it began to turn, and was soon as black as ink—one putrefying mass. Iron was an antiseptic, and pickled the sewage, and consequently was not the best means of treating sewage. Lime was not such an antiseptic; it tended to destroy; it had some effect in clarifying, but the effluent often underwent decomposition. He had a town under his care where the water left the tank clear as

Mr. Latham. crystal, but after running through ditches about a mile before getting into the river, it was quite black. The authorities were now abandoning that process, and were going to put the sewage upon the land. Every known earthy and mineral salt had been utilized, even the most expensive, and all certainly produced in their way good effects; but in order to get complete purification some better method was necessary than the mere treatment with a very minute quantity of a salt giving off oxygen. Land, even of limited area, combined with a precipitating-process, was the best plan that could be adopted; and where land in sufficient quantity could be obtained, it was undoubtedly the simplest and cheapest method. Mr. Crimp's Paper was one of extreme value, giving some very important statistics with reference to the treatment of sludge; and he quite concurred in the remarks of Mr. Mansergh as to the success of the works at Wimbledon. The question was one which ought to occupy the attention of engineers. It was strange that down to the present time it should cost so much to press sludge. Some other method might be introduced by which the water could be got rid of, for the problem was simply that of pumping 1,200 gallons of water 200 feet high, and which operation now cost from 2*s.* to 3*s.* He had used the method of applying air in what was called the monte-jus apparatus, and also direct pumping. His own view was that direct pumping was far the most economical, and he had had a set of sludge-pumps at work some years pumping into a filter-press at the tanneries at Nantwich. These pumps had two sets of suction-valves and two sets of delivery-valves arranged one set before the other. If there should be any clogging, the chances were that both valves would not clog. They drew the sludge horizontally 80 or 90 feet, then the suction dipped down to the bottom of the tank, and it was thrown back again through the delivery-pipe a similar distance, and passed through the filter-presses. The reason for adopting this plan was to enable the sludge-pumps to be put in the existing engine-house. That plan had worked quite satisfactorily. If the pumps would work under such a condition as that, and give a duty of about 40 per cent. of the power applied, it was much better than using the air where only one-sixth of the duty could be got out of it, or 16 per cent., as shown in Mr. Crimp's experiment. The filter-press seemed to be looked upon as quite a modern device, but it was nothing of the kind. It was used thirty years ago at the Leicester Sewage Works, by the late Mr. Thomas Wicksteed, M. Inst. C.E., who then adopted one of the best methods ever devised. Instead of using air or pumping direct into the

press, he erected a stand pipe and pumped the sludge into it, and from that he produced what was called "Leicester bricks." The Leicester Company spent £50,000 upon the works, but they turned out a great financial failure, and ultimately came into the possession of the Corporation of Leicester without charge. Another device that Mr. Wicksteed introduced had been very largely used for other purposes—a centrifugal drying-machine, which had been adopted in washing-factories. It was originally produced for the purpose of separating the water from sludge. Seeing that the filter-press had been revived, it was a question whether or not some form of that centrifugal machine might not be more economical to get rid of the small quantity of water in the sludge at a less cost than at present. If engineers would direct their attention to that point he was quite certain, considering the small amount of work to be done, that the plan was feasible, and, that in future, sludge in a compact form could be produced at far less cost than at present. Mr. Latham.

Mr. J. C. MELLISS observed that he had spent many years in personally conducting practical experiments with reference to the chemical treatment of sewage, and he had tried a large variety of chemical precipitants, the outcome of which was that he had found that lime of itself did not produce good results, that sulphate of alumina produced much better results, and that the addition of some salt of iron produced the best results. He agreed with Mr. Baldwin Latham that perfect purification could not be got by chemical treatment, but that to raise the standard of purity to any high extent further steps must be taken. The filtration of the effluent water, after chemical treatment, through land, seemed to him to be the best course to pursue. As to whether land treatment simply was better than chemical treatment combined with land filtration, he rather differed from Mr. Baldwin Latham. He thought if the two were taken together, in a large number of cases they would not be found to be more expensive, and the results would be better. He had himself tried the proportion of 3·7 grains of lime, and 1 grain of iron per gallon, not upon London sewage, but upon sewage which would compare very favourably with it, namely, domestic sewage, where the town was fully provided with water-closets, where there were no manufactories, and where the sewage was about 50 gallons per head, and he found that they afforded no useful result whatever. Mr. Melliss.

Sir ROBERT RAWLINSON, C.B., said that as far as he knew no chemical ever used was a purifier, nor was it the best clarifier. Whenever precipitation was attempted and carried out, he knew of Sir Robert Rawlinson.

Sir Robert Rawlinson. no place where the annual cost was less than £2,000 for each million gallons of sewage treated per day. As to the disinfection of excreta, the late Dr. Parkes carried out some exhaustive experiments at Netley for the Army Sanitary Committee—so persistently as to have seriously affected his health—and he came to the conclusion that to disinfect with any advantage a cubic foot of excreta would cost in the best chemicals as much money as clearly to put it out of the field to disinfect on a large scale on the score of expense. Whatever the Metropolitan Board of Works expected to accomplish by the methods it was now adopting, the result must be similar to what had occurred over and over again, namely, failure to purify the sewage, as whatever money might be spent in applying chemicals in precipitating and abstracting sludge, if the effluent was turned into the Thames it would again putrefy, and the river would not be purified, as proved on other streams where the experiment had been tried. As to the use of perchloride of iron as a disinfectant, when that had been carried out on a considerable scale, and where a comparatively clarified and pure-looking effluent had been turned into a small stream in hot weather, the water had been of such a character that where milch cows had been permitted to go into the fields, and get access to it, the milk had been spoiled. As to sewage-irrigation, it was now being carried out on a large scale both in Paris and in Berlin, and he believed that if proper conduits were constructed for London, and the sewage applied in its freshest state to a sufficient area of land, it would need no chemical treatment whatever—no precipitating process, because the crude sewage as it came from the Metropolis might be floated on to the land in the open country without causing a nuisance, as had been done at Bradford, Nottingham, Birmingham, Croydon, Doncaster, and several other towns. As to precipitating sludge from the Metropolitan sewage and barging the same to sea, could the Board be really serious? There were at least some 200,000,000 gallons of sewage per day—probably on an average more. But take 200,000,000, and 5 tons of silt and sludge in each million gallons. This would give 1,000 tons of sludge per day, 365,000 tons per annum. Did the Board seriously propose to barge this volume and weight of sludge down the Thames and to sea, a distance of 50 miles; an amount of 7,000 tons per week? If so, how many barges would be required, and what would the working cost? And all for what? Not to purify the Thames, as the effluent would foul the river in summer; not to purify the sites of Barking and Crossness, as these would be far fouler than ever; they would, in fact, be

Sir Robert Rawlinson.

intolerable in summer. On the other hand, deal with the sewage as at Berlin and at Paris, and at a number of places in England, as at Birmingham, Nottingham, Bedford, Croydon, and Doncaster, and there would be least cost to the ratepayers of London, and an enormous benefit conferred on the country. Sewage-conduits might be made from the existing stations at Barking and Crossness, through agricultural districts, for 20 or 30 miles in length, from which conduits crude sewage might be distributed to land on both sides as required by farmers, paying 5*s.* for each 100 tons, some 40,000 or 50,000 acres of land being easily within reach of the conduits and the sewage. If a farmer took 100 tons per acre in spring he would, at a cost of 5*s.*, double his hay crop; and, for a second dressing in the autumn at 5*s.*, he would double his aftermath. This would be the simplest and easiest mode of distributing sewage, and 10*s.* per annum per acre to increase the produce of the land four-fold in these bad times would be an advantage. But sewage could be used to grow other crops besides hay and autumn grass.

Mr. Jerram.

Mr. G. B. Jerram stated that he had succeeded at Walthamstow in getting good results. The authorities had been in litigation with their neighbours below for the last ten years, but by the aid of new machinery, and the altered way of dealing with the sewage, they had given satisfaction, and during the last eight or nine months had been complimented on the results achieved. The sludge was used as at Birmingham, and was dug into the ground. The produce of thirty-six thousand inhabitants was placed on 1 fresh acre of land every month; it became dried in a month or so, and the crops produced were very good. There were 36 acres of land, so that in three years' time it would be necessary to come back to the original acre on which to put the sludge. The difficulty was with the black sludge formed at the bottom of the stream; when the weather became hot the black mud putrefied again and became offensive. That had produced the wretched state of the Lee and of the Thames. It was more apparent where the volume of water in the stream was nearly equal to the volume of sewage which flowed into it. To get a certain result, in the mixture of two compounds, it was necessary to know exactly the quantities that had to be adapted to each other. The quantity of sewage varied at different times of the day, being much larger in the morning than at night, and the difficulty was to apply the exact amount of chemicals to the varying quantity. It was in consequence of not doing this that the black sludge appeared at the bottom of the streams. In the morning the sewage, which

Mr. Jerram. was of course of a very light nature, was treated with a certain amount of chemicals, the attendant putting on what he thought was requisite, the consequence being that the effluent was highly charged with chemicals. He had proved by experiment that an effluent highly charged with chemicals acted on the organic matter in the stream, precipitating it as black mud at the bottom. At another time, perhaps, the sewage would not be treated with the requisite quantity of chemicals, and the effluent would be highly charged with sewage. Then again, when the requisite quantity of chemicals was added, the sewage that had been discharged an hour or two before was precipitated, and sludge was formed at the bottom of the stream. He had visited nearly all the towns in England where sewage was treated chemically, and had found that that was the result. By using automatic machinery, whereby the volume of sewage itself regulated the inflow of the requisite amount of chemicals, it was possible, to a very large extent, to minimize the effect to which he had referred. Both by day and by night the requisite quantity of chemicals could be added according to the flow of the sewage. It was in consequence of adopting that system that he had obtained such good results, and he thought that if more attention were paid to the mechanical arrangements for mixing the chemicals with sewage far better results would be secured. Let the chemists say what the proper proportions were, and engineers could provide the mechanical means for mixing them. He had seen and noted another machine for dealing with sludge in precipitating-tanks, namely the Astrop machine. He had seen several experiments in which sludge was taken direct from the tanks and passed through a certain number of vacuum rollers, by which the water was extracted, and in the space of four hours the sludge was in a state of dry powder.

Dr. Edmunds. Dr. JAMES EDMUNDS, Medical Officer of Health for St. James's, Westminster, said that he would offer only a few remarks upon those chemical and biological questions which had not yet been exhausted. The proposal, to put protosulphate of iron and permanganate together into sewage, he could only characterize as an astounding one. The protoxide of iron would instantly denude the permanganate of its spare oxygen, and become sesquioxide. The lime would at once combine with the carbonic acid of the sewage, and be precipitated as chalk. The chief result of these chemicals would thus be to load the sludge with inert sesquioxide of iron and inert chalk, while loading the effluent with the inert residue of the permanganate salt. The use of lime in larger quantity, as an effective precipitant, would spoil the sludge by

dissipating its ammonia and by making the sludge-cake putrescent; it would spoil the effluent by making it alkaline, and it would create an intolerable nuisance by defiling the atmosphere with ammoniacal emanations. Mr. Dibdin's Paper, he thought, was one of which that gentleman would not be proud in future years, its chief merit having been to serve as a point of departure for this valuable and instructive debate. One point on which he was obliged to differ from Dr. Tidy's admirable critique was in reference to the use of iron. He did not doubt that, in the curious oxygen-carrying power of iron there was a power which, if properly applied, might be made to continuously and automatically oxidize the organic refuse in sewage. In living animal blood, this most remarkable oxygen-carrying power of the iron was the mainspring of all animal life. Blue London clay was coloured by ferrous sulphide, which, on exposure to the air, turned yellow by absorbing oxygen; yet this yellow clay, if left in contact with organic matter, was reduced again by deoxidation, and a blue halo thus caused would be seen in yellow clay wherever a fossil was imbedded in it. The action thus described, however, was not to be got by mixing a protosalt of iron with a permanganate. It was only to be got by the use of a persalt of iron, and the sesquichloride would be the cheapest and most effective. This should be used, not with lime, but with a cheap aluminium chloride, which was the best basis for a precipitating process. Previously to the addition of these salts, however, there might sometimes be added, in alkaline sewage, as much magnesian salt as would precipitate the ammonia and phosphoric acid as basic phosphate. Dr. Dupré had attacked the Native Guano Company's process although, as he understood, he had never even visited Aylesbury in order to see and study the process. Dr. Edmunds, in his own studies of the sewage question, had applied to the Native Guano Company for permission to visit those works; that permission had been at once granted, and the Manager attended and showed him everything. He himself had learned much there, and he recommended every one who would see what precipitation could do, to write for permission to inspect those works. At Aylesbury there would be seen a torrent of foul sewage running into the works at one end, and a bright clear effluent running out at the other, while a valuable manure was made out of the sludge and its precipitants, and the whole process was free from nuisance. He observed from the newspapers that the Corporation of Kingston and the Improvement Commissioners of Surbiton, after prolonged consideration of all existing schemes, had combined and signed a con- Dr Edmunds

Dr. Edmunds. tract with the Native Guano Company to relieve them of their sewage at a poundage upon their rates. He believed that, as to safety and efficiency, the native guano process was the best at present before the public, and, if it could be carried out at any reasonable price, he was convinced that Kingston and Surbiton had done wisely to get rid of the responsibility. The precipitation process depended entirely upon skilled and efficient management, and could be done best by a responsible company. The description which had been given of sewage was most imperfect. As to the mineral and dissolved matters of sewage, their treatment was a mere matter of scavengering. Then this should be made quite clear, namely, that all matters in solution were free from infectiveness and from all danger of multiplication after the manner of living germinal matter. But as to the suspended organic matters, in them there were germinal particles which, under suitable conditions, had infinite capacity for multiplication, and which, when imbibed in drinking-water, were the means of propagating all the great intestinal epidemics. In the district of St. James', now under his charge as Health Officer, there was, some years since, in Broad Street, Golden Square, a pump, the water from which contained 107 grains of solid matter to the gallon, including 11¼ grains of chlorine and a large quantity of nitrates and organic matter. Practically this water was sewage and street slop, merely filtered through some 30 feet of gravel and fine sand which lay there upon the London clay, yet it was in great request as drinking-water and was regularly fetched from long distances. People who had acquired a taste for it could never relish any other drinking-water, and it was universally regarded as "splendid spring-water." Now this water was drunk by a whole neighbourhood for years, and never did anybody harm. But, at the end of August 1854, a choleraic attack occurred in the house abutting upon this pump. The evacuations of the patient went into an old rotten brick drain which passed by the wall of the well, and it was afterwards demonstrated that the drainage of this house had for many years contributed to give that body and flavour which had brought this water into so much request. Shortly after those choleraic excreta had passed into that well, over five hundred fatal attacks of cholera occurred within 250 yards of its pump in a period of ten days. This incident illustrated what was the main point to be kept in view in the treatment of sewage—*i.e.* the destruction of those pathogenic germinal particles which, when they got into waters charged with organic matter, found food on which they multiplied and produced cholera, typhoid, dysentery, or, under a certain

temperature, yellow fever—the four great intestinal epidemics which were propagated chiefly through drinking-water. Now to pour into the Thames an effluent merely superficially deodorized, as proposed in Mr. Dibdin's Paper, would assuredly be followed by that poisoning of the river which had been predicted by Sir Robert Rawlinson. It had been said, again, that these germs could only be dealt with by means of other microbes which would devour them much as a ferret might suck out the contents of an egg, and so prevent its growing into a chicken. But he denied altogether that this was the only, or even the best, way in which these germs could be destroyed. Not only might an egg be killed by setting a ferret to suck its contents out, but also by boiling it, or by poisoning it, or by breaking it up. He believed that these pathogenic germs were best dealt with by a good precipitation process; that in this way they could be entangled, coagulated and carried down into a sludge, in which they could safely and easily be desiccated, and then be carried out on to the land. They would there undergo decay, just like dead eggs, and be safely got rid of, while at the same time they would fertilize the land. But towns must be made to realize that, whatever be the cost, they would have to dispose of their sewage, and to dispose of it without poisoning their neighbours. Dr. Edmunds.

Mr. W. SHELFORD wished to call attention to the fact that Mr. Dibdin had advocated the use of a very small quantity of chemicals as precipitants. That had been pointed out by him as very desirable, if not necessary, on other grounds, in a Paper, eleven years ago, "The Treatment of Sewage by Precipitation."[1] It was satisfactory to find that chemists, for reasons of their own, had come to the same conclusion, and also that they had adopted the use of solutions, as at Buxton, Wimbledon, and other places. It was obvious that in that way a large quantity of inert matter was excluded from the sewage, and that the sludge was thereby diminished, and if the chemical effect was increased the advantage was very great. Mr. Baldwin Latham had alluded to the quantity of suspended matter in the sewage, as stated by Mr. Dibdin, namely 27 grains per gallon, which he thought was very small. Mr. Shelford was of the same opinion. In 1871–2 he constructed the works at Crossness for the Native Guano Company, working the A B C process, where a sum of £25,000 was spent, and one of the great difficulties was to get a true sample of Metropolitan sewage. The company was to take for experimental Mr. Shelford.

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[1] Minutes of Proceedings Inst. C.E. vol. xlv. p. 144.

Mr. Shelford. purposes 500,000 gallons per day, and the point at which he proceeded to tap the sewage was a culvert, into which the whole of it was raised by pumps, and was kept in a state of agitation. In those works 11,672,000 gallons were treated, and Mr. Keates, the chemist of the Metropolitan Board, reported in 1873 that the difference between the dry precipitants and the dry manure derived from the sewage was 61 tons, or 82 grains per gallon, which Mr. Shelford believed fairly represented the suspended matter contained in the sewage. That was also confirmed by his experience at Battersea on a large 5-foot main sewer, where, from experiments continued for some time, it was found that the suspended matter was about that quantity. But when it was remembered that a gallon of sewage amounted to 70,000 grains it was easy to see how difficult it was to obtain a correct average of the quantity of suspended matter. It would be interesting if Mr. Dibdin could say where, how, and when he obtained the samples which gave such a remarkably low average. Some years ago there was a considerable difference of opinion on the sewage question compared with that prevailing at the present time. From 1869 to 1876 the idea presented itself to many minds that sewage was a valuable commercial commodity, and concessions of sewage were asked for, and obtained in some cases, from corporations, on terms which must have been ruinous to the concessionnaires, if the undertakings were ever carried out. Again, in 1868 or 1869, Mr. Sillar obtained a patent for the A B C process, the speciality of which was the purification of sewage by the use of blood; and it was said by Mr. Sillar, and others, that the discovery was due to his reading in the Scriptures the words "almost all things are by the law purged with blood." In 1871 Mr. Baldwin Latham, speaking on irrigation, said that the Croydon Sewage Farm Company paid 15 per cent. dividend, and carried 15 per cent. forward to the next account, making a total profit of 30 per cent. on the capital.[1] In 1876, in the discussion on his Paper on "The Treatment of Sewage by Precipitation," Sir Joseph Bazalgette said that precipitation processes were palliatives, but not cures; and in the following year, in an exhaustive Paper on "The Sewage Question,"[2] Mr. Norman Bazalgette condemned chemical treatment on account of its inability to deal permanently with sewage on a practical scale. That was the position from ten to seventeen years ago; but at present it was very different. The value of sewage was depreciated; in fact, it might

[1] Minutes of Proceedings Inst. C.E. vol. xxxii. p. 399.
[2] *Ibid.*, vol. xlviii. p. 105.

be said that its depreciation was as great as its former appreciation; possibly a medium course might be safest, and might turn out to be the right one. Mr. Sillar, in the present discussion, never mentioned blood. Recently, Dr. A. Carpenter, of Croydon, defending irrigation, had stated in another place, "There may be no actual profit to the farmer . . . . but the production of the food must be a benefit to the country."[1] With regard to the Metropolis, the Metropolitan Board of Works had decided upon adopting the "palliative," as it was called by Sir Joseph Bazalgette, and had entered into a contract to the amount of more than £400,000 to carry out precipitation or chemical treatment upon a practical scale, or at all events upon such an extensive scale as would make the outfalls permanent precipitation works for a long time. He only mentioned those facts to show that the satisfactory solution of the sewage question was almost as far off as ever, and that engineers could not afford to give too confident opinions until they came within a measurable distance of such a solution. With regard to the progress by engineers in the disposal of sewage-sludge, he believed that during the last ten years there had been practically none whatever, except in the improvement of the presses. He had seen those at work at Wimbledon, and they were certainly working very satisfactorily. They produced a sludge-cake which contained 50 per cent. of moisture, and reduced the volume of sludge $\frac{4}{5}$ths. That was no doubt a great advantage in places like Wimbledon, and many others; constituting, in short, the difference between success and failure, but it was no solution of the sewage question. Mr. Crimp had said that, "If, however, sewage-sludge is to take and retain its place as a manure of superior class, in order to save carriage and render it more suitable for application to land, it is necessary to go further than treat it in a filter-press. The sludge-cake should be dried and pulverized, and as its quality must vary with the occurrence of storms, which bring quantities of mineral detritus into the settling-tanks, every endeavour should be made to turn out a manure of uniform quality, either by fortifying weak samples or by thorough admixture of the mass." No doubt that was true. Sludge-cake could not compare with stable manure. At some stables which he had built at Deptford for three hundred horses, the contract price for the manure, which was the best price that could be got, was 2*s.* 9*d.* per ton. Mr. Crimp had shown that he had reduced the cost of the production of sludge-cake to 2*s.* 6*d.* per ton; but seeing that it had to contend against prejudice, and to

Mr. Shelford.

[1] Journal of the Society of Arts, vol. xxxv. p. 222.

Mr. Shelford. compete with farmyard manure, which was abundant and efficient, it was not likely that it would ever attain to any great success. The conversion of sludge into portable manure worth £4 per ton in the market—the lowest price at which artificial manure was saleable—was a serious and difficult matter. A full description might be seen in Mr. Norman Bazalgette's Paper of the different processes that had been tried up to ten years ago.[1] As to the Metropolis, Mr. Shelford approached the subject with an intimate knowledge of the question. He had constructed the works for the Native Guano Company; and like other engineers he had been connected with the arbitration between the Metropolitan Board of Works and the Thames Conservancy; with that knowledge he ventured to say that, unsatisfactory as it was in principle, and from many points of view, he thought that the proposal to ship the sludge to sea was the readiest way of getting out of the difficulty at the present time.

Dr. Thudichum. Dr. J. Thudichum regretted that the actual points at issue had not been discussed. The subject before the Institution was whether the process, as described by Mr. Dibdin, was a good process for solving a question which had engaged the attention of the engineers and chemists of the Metropolis for many years. Having had the opportunity of inspecting the works at Crossness, and also of inspecting the River Thames at various periods, and having studied the question of the treatment by pressure of the sludge precipitated by chemical means in various towns in England, and at various periods, he, as a sanitarian and as a tax-payer, had come to the conclusion that this was a highly practical and very useful process, and he rejoiced to hear that the precipitation process was going to be adopted by the Metropolitan Board of Works. Nothing could be more simple than to put into a gallon of sewage 3·7 grains of caustic lime in solution and 1 grain of ferrous sulphate, whereby a clearance was produced of a very satisfactory nature. No doubt in warm weather a secondary process might be necessary to make the effluent less objectionable than it would otherwise be, namely, the addition of a quantity of permanganate of soda, that remarkable agent which was first introduced to the notice of sanitarians thirty years ago by Mr. Condy. Dr. Tidy had stated that Mr. Dibdin had made such a remarkable mistake as to say that a ton of lime cost £1, whereas he knew from unquestionable authority that it only cost 12*s*. That statement had no doubt arisen from the fact that Dr. Tidy

[1] Minutes of Proceedings Inst. C.E. vol. xlviii. p. 105.

had mistaken a cubic yard for a ton. Another statement had been made by Dr. Edmunds, to the effect that the addition of permanganate to the liquid treated with lime and iron would quickly lay hold of the sub-oxide of iron, and thus lose the oxygen. He had forgotten that before the permanganate was put in, the iron was out again. It was strange that two gentlemen should suppose that the Chemist of the Metropolitan Board of Works could be found napping in that way. He congratulated the Metropolitan Board of Works on having come to the resolution to which he had referred. The cost was not unreasonable. The Thames would be purified, and there would be no difficulty in carrying out the process; the deposition of sludge on the shores of the Thames would cease, the material would be taken out to sea, and there would be an end of the existing troubles for a long time to come. Dr.Thudichum.

Mr. G. E. EACHUS said he wished to fill up a gap that had been left in Mr. Crimp's Paper, by giving the quantity of lime used at Edmonton per 1,000 gallons when the Hillé process was adopted. It was from 7 to 9 gallons per grain of lime, $1\frac{1}{2}$ grain of chloride of magnesium, and $\frac{1}{16}$ grain of carbonated creosote. The quantity of sludge was rather more than $\frac{1}{2}$ cubic yard daily per thousand inhabitants. The total quantity in the year carted was about 4,000 cubic yards, and the cost of the carriage and spreading of the sludge was about 1*s.* a cubic yard. With reference to Mr. Dibdin's Paper, he was inclined to think that a chemical, which could be placed practically in the closet for disinfecting the sewage, would be of material assistance in removing the nuisance. The only question was, whether that chemical would not be such as to cause a deposit in the sewers. He also agreed with Mr. Dibdin in thinking that aeration, both in the sewers and afterwards for the effluent, was a most important matter. With reference to sludge disposal, he could not agree with Mr. Crimp in looking so favourably on sludge-presses. In certain cases, no doubt a sludge-press was a last remedy; but under ordinary circumstances he thought that it laboured under the great disadvantage, that it squeezed out a liquid which was a black and foul one, and produced a manure which was of no value. The dry manure was certainly reduced to a minimum quantity, and consequently the cost of cartage was reduced *pro tanto;* but he had heard of no means by which the black, foul liquid could be got rid of. The last remedy was, that it was run back into the sewer to go through the tanks, and so on in a circle. That seemed to be a very weak point in the pressing of Mr. Eachus.

Mr. Eachus. sludge. He had always had in mind the difficulty of getting rid of sludge when he built the tanks at Edmonton, and he kept them well above the ground so that the invert of the tanks might be 2 or 3 feet above ground level; the sludge could then be run out through the bottom of the tank through a stone-ware pipe. For some years that was done, the sludge being run on to the adjoining land and there allowed to dry. That sludge accumulated to a very great extent, and there was a considerable expense in cartage. At 4,000 cubic yards a year the amount was about £200 for carting it on to the farm and ploughing it into the land. Having kept the tanks at a certain level and finding that the pipe under the tanks was always clear, that the sludge never stopped there (there was always a certain amount of liquid when the sludge was emptied from the tanks), it had occurred to him that the expense might be saved by continuing the pipes and running the sludge on to the low-lying land; and this was accomplished at a cost of only £200 or £300. He had also found an advantage in distributing the sludge in different parts of the farm, and not merely ploughing it into the low-lying parts. In order to do that, he had connected the sludge-disposal pipes with the distributing pipes, which took the effluent water after it left the tanks, and by putting a little head on he could run the sludge to almost any part of the farm. With reference to the disposal of the sludge and its utilization, it appeared to him that, according to the chemicals used, the sludge must have more or less value for different crops. It was not only desirable, as Mr. Dibdin had said, to work so that different organisms which were beneficial might be generated, and certain other organisms which were injurious might be destroyed or burned up, but also to look to the vegetable organisms that required different kinds of food. Dried sludge was unsuitable as food for vegetables. As to London sewage, he could not agree with Mr. Dibdin. He did not like the idea of chemical sewage works on such an enormous scale. He would much rather have the sewage pumped from the present works, so as to command all the land, which was now good for next to nothing, along the valley, and he thought that if the Metropolitan Board was to advertise for such land, it might get 20,000 or 30,000 acres at a very low rate. The sewage could then be pumped on to the higher part of it, and allowed to run away to sea in open carriers, so as to give it plenty of aeration; and if no profit could be made out of the crops, it would at least cover the cost of the purchase of the land and increase the market produce. At Edmonton, since the chemical process had been given

up, the expenses had been more than covered. Even last year, when the crops generally were so bad, under the management of the farm-bailiff very fair prices had been obtained for the standing crops, ranging from £6 to £16 an acre. Mr. Eachus.

Mr. A. GILES, M.P., said he should be sorry to think with Mr. Shelford that sewage-disposal had not made much progress in the last few years. In 1884 he was Chairman of a Committee of the House of Commons, before which the Lower Thames Valley Main Sewage Scheme came, and after examining what had been done at Chiswick, and taking a good deal of evidence upon the subject, the Committee came to the conclusion that the scheme, as then proposed, to concentrate the sewage of all the districts above Richmond somewhere about the Soap-works at Barnes, would lead to intolerable nuisance. The scheme created such an opposition in the neighbourhood, that the Committee, after having heard everything that could be said in favour of it, and without waiting for what the opponents said against it, came to the unanimous decision that it would not work. Since that time, only three years ago, those districts which were to have been comprised in one huge scheme had adopted their own methods of draining, some of which, he believed, were worked very satisfactorily. It was said at the time that, by the use of chemicals, the effluent thrown into the Thames at Chiswick was perfectly inodorous, but several bottles of it were brought into the Committee-room, which, as soon as they were opened, emitted such a fume that they had to be removed. He did not think that there need be the same difficulty with proper chemicals in small districts, and he could vouch for the fact that at Southampton, where the drainage was mixed with certain chemicals, and ejectors were used, when the sludge was thrown into a pit and mixed with cinders and soil there appeared to be no nuisance. But it was different in a small place like Southampton, where there was a demand for the refuse and sludge, from what it would be in a place like the Metropolis, with four millions of inhabitants. He confessed that he thought the problem was not yet solved, and he considered it not at all improbable that, before it was solved, the mode suggested by Mr. Dibdin, of taking the sewage of so large a population into the sea, would prove the cheapest and the best remedy. Mr. Giles.

Dr. T. STEVENSON recognized in Mr. Dibdin's Paper an effort to solve the sewage question, so far as it concerned the Metropolis; but he should be glad if, before it was applied to London, it could be applied, not on a very small, but on an extensive scale, under some other conditions. The great difficulty would be, not the preparation Dr. Stevenson.

Dr. Stevenson. of an effluent which under ordinary conditions, when cast into a stream, would give rise to little or no nuisance, but an effluent which when accumulated in immense quantities in a relatively small quantity of fresh water, would again enter into putrescence in hot weather, before it had become sufficiently oxidized or exposed to such fresh influences, like the lower vegetable and other organisms, as would convert it into inorganic constituents, or into the tissues of animal and vegetable life. But he recognized that Mr. Dibdin had placed on an experimental basis what had only been dimly perceived before with regard to the economical use of chemicals; for he had shown, what had been ascertained before by practical experience without any explanation, that the use of a minimum quantity of lime in solution would effect as much in the way of precipitation as a much larger quantity, if simply mechanically mixed, or only partially dissolved. At Bradford, for instance, the conclusion had been arrived at empirically, that, using about 15 grains of lime to the gallon, it must first of all be mixed in the proportion of 90 grains of lime to the gallon, and be well worked up again and again, to get the most effective results. That was what Mr. Dibdin had found: 90 grains being about the maximum solubility of lime in water. Mr. Dibdin had put that experience on a more scientific basis, and shown that in solution lime was greatly more effective than when mechanically suspended or only partially dissolved. With regard to the use of iron, he recognized fully as a chemist that in a ferrous or proto condition it was an effective carrier of oxygen, taking this from the air and handing it over to the sewage, again to take another portion from the air; but he had ascertained, by the examination of sewage-effluents that had been treated with lime in conjunction with other materials, that for a long time the effluent water did retain in solution, when well limed, a certain quantity of iron in a proto condition. Of course there was always this disadvantage with regard to the use of iron, that it created a sentimental grievance—that it blackened the mud banks. The chemist, however, recognized in that a beneficial influence, whereas those who simply looked at black matter as almost necessarily offensive, regarded it from a different point of view. As to the disposal of the sludge, there was much to be learned; although the filter-press was a very efficient engine for removing sludge and converting it into a portable condition, where it could be applied to land or burnt, or disposed of without nuisance, it must also be recognized that if sludge-presses were to be used all over the kingdom, the material would become much

more costly, and that this method of disposing of the sludge was an expensive one. In all such cases there was the great difficulty of the disposal of the pressed liquid, which was always highly concentrated. It contained organic constituents and nitrogenous constituents, necessarily putrescent under certain conditions, and there was a further difficulty to contend with, that lime had to be used, and when it was used in large excess it had a highly solvent action. Any one who had examined, as he had done, the effluent from the Wimbledon Works would recognize it as a saturated solution of lime, and the difficulty was to get rid of that lime. His own opinion was that the most effective means of getting rid of the effluent was to dilute it with clear water and apply it to the land, instead of, according to the general plan, turning it back again into the main sewage to be again treated *da capo*. He thought that the latter course often created great obstacles to the further clarification of the sewage. Mr. Crimp, however, had informed him that he had not found that difficulty, but Dr. Stevenson knew that it had in other cases proved very serious. Although a chemist, he looked with much interest on the question of carrying sludge to sea, and if it could be carried to a sufficient distance, and done economically, he saw no reason why it might not be effected without nuisance. If engineers could accomplish that result a great step would be taken towards solving the sewage question for the Metropolis. Dr. Stevenson.

Mr. FREDERICK JAMES LLOYD said it had been stated in Mr. Crimp's Paper that manure made from sewage-sludge was superior to ordinary farmyard manure. He wished, as an agricultural chemist, to raise a protest against any such statement, and he felt certain he was expressing a view which would be held by every farmer in the country in asserting that no such manure could be made from sewage-sludge. Considering the fact that farmyard manure was made upon the farm, and that the sewage-sludge manure had to be carried to the farm, the expense of carriage alone outweighed any beneficial effect that the latter might have. Sewage-sludge contained from 1 to 2 per cent. of a phosphate of some kind and a certain amount of nitrogen. It was not known that the phosphate was phosphate of lime; even if it were, a manure could be bought containing 25 per cent. of phosphate for £2 10*s*., and superphosphate was twice as valuable as any phosphate that could be present in sewage-sludge. Nitrogen also could be obtained by the farmer for agricultural purposes in a form twenty-five times more concentrated than in a similar Mr. Lloyd.

Mr. Lloyd. quantity of sewage-sludge, and at a price varying from £10 to £12 per ton. It was known that the nitrogen in sulphate of ammonia, or in nitrate of soda, was available for plants; it was not known that the nitrogen of sewage-sludge was available, and considering that its compound had resisted the decomposition of the sewage, and the decomposing action of lime, it might be confidently assumed that it was in a very stable form, and would not readily decompose and yield its nitrogen to the plant. He thought, therefore, that on all sides sewage-sludge might be considered as practically useless to the farmer, because it cost too much for him to apply it. But it might be useful to make a sewage-sludge in the treatment of sewage, and if the effluent water was to be used for irrigation purposes, he thought a little more attention ought to be paid to the nature of the chemicals which got into that effluent water. If the effluent was to be applied to plants, it was wrong to put into it a substance which was injurious to their growth. All the tillage operations of farming had in view the oxidizing of substances in the soil, while plants would not grow in any soil which was either alkaline or acid. Sulphate of iron, if used in excess as a precipitant, passed into the effluent water; being acid, it was one of the most injurious compounds to the plant that could be applied. There were many acres of land in Ireland where nothing could be grown, because of the sulphate of iron present in the soil, and it took years of cultivation, and a large quantity of lime, to bring that sulphate of iron into such a form that it was no longer injurious. With regard to the subject of precipitation; in studying the changes which took place in silage, he had found that the decomposition was at times very similar to the decomposition that went on in sewage. Part of the substance was continually decomposing, part of it appeared to be very slowly acted upon; and in the process of decomposition substances were formed which would combine with any metallic hydrate to produce a precipitate of a very stable nature, and all those compounds were more or less nitrogenous. If further decomposition followed those compounds were broken up into others, which were not precipitable by metallic hydrates; the conditions of precipitation were a neutral solution or liquid and some compound which would readily precipitate the metallic hydrate. Copper sulphate, iron sulphate, and alumina sulphate would easily give precipitates with this organic matter; they were flocculent, and would carry down any substances in the liquid that were not in solution. He thought, therefore, that much that had been said, with regard

to the large quantity of chemicals necessary, pointed to the fact that the action of the chemicals had not been studied; inasmuch as the most minute quantity of metallic hydrate was sufficient to combine with the organic compounds and to precipitate them. Much more of the chemical might be put into the liquid, and more of the metallic hydrate might be precipitated by using an alkaline substance like caustic lime, but not any more organic matter in combination would be brought down. If the advocates of the utilization of sewage studied the question more from a scientific point of view, instead of endeavouring to bolster up patents or to make farmers believe that they could produce a manure which was of great value, they would find that only a small quantity of precipitating agent was necessary to purify sewage, and was preferable whether they used the sewage-sludge or the effluent upon the farm. Mr. Lloyd.

Sir JOHN COODE, K.C.M.G., observed that he should like to correct a little misapprehension into which Mr. Giles had inadvertently fallen. He appeared to be under the impression that the suggestion of taking sludge to the sea was one that had emanated from Mr. Dibdin. As a member of the late Royal Commission on Metropolitan Sewage Discharge, he wished to call attention to the fact that the disposal of the sewage by taking it to sea was one of the recommendations of the Commission. He had reason to think that in some quarters there existed an impression that, in making that recommendation, the Royal Commission was taking up a rather "big" question, but he was not of that opinion. Accepting Mr. Dibdin's figures as correct, that it was necessary to deal with 3,000 tons of sludge per day, that was not a very large quantity. It only amounted to 1,095,000 tons annually, which was by no means large. If reference was made to what had been done by the River Tyne Commissioners, it would be found that, in the course of the twenty-five years ending December 1886, they had taken to sea 77,109,749 tons, or more than 3,000,000 tons yearly, which was three times the quantity that would have to be dealt with in the case of the Metropolitan sewage. In one year alone, 1865, they dredged and took to sea, 18 or 20 miles distant, no less a quantity than 5,250,000 tons. In the face of those facts, it could not be fairly said that the proposal made by the Royal Commission was by any means an extravagant one. Sir John Coode.

Major LAMOROCK FLOWER remarked, that the main point of Mr. Dibdin's Paper was that the disposal of London sewage should be regarded as an exceptional case, and that the volume being so Major Flower.

Major Flower. vast, and its condition so varying, ordinary modes of sewage treatment could hardly be said to apply to the case; that it was, in fact, impossible to do more than roughly treat it chemically, and then throw the residue away or take it out to sea, and hope to see the last of it. Hope had often told a flattering tale. He thought the idea wasteful and extravagant. More than ten years ago he suggested that sewage-sludge should be used for filling up low-lying land, putting its value at the lowest possible amount. He referred to this in his evidence before the Royal Commission on Metropolitan Sewage Discharge, and he adhered to it now. He fully admitted the vastness of the question for London and all its difficulties. He was certain that ultimately the outfalls must be taken lower down the river, and the Canvey Island scheme of Lieut.-Colonel Jones and Mr. Bailey Denton seemed to point to a final and satisfactory solution of the question. He would be the more pleased if this idea were carried out, as it would provide an outlet for the Lee Valley sewer, in which he was interested with Sir Joseph Bazalgette, and Messrs. Law and Chatterton, MM. Inst. C.E., and the requirements of the residential districts of the Lee Valley would before long make the construction of that sewer a necessity. Not long ago the Metropolitan Board of Works took pains to make out a case that there was no nuisance at the outfalls; perhaps this contention was right scientifically. The noses of the public, however, seemed to point to a reverse conclusion, and it became desirable to appease the popular indignation. He should have liked to have heard Mr. Dibdin give the results of the various modes which were supposed to have been tried at the outfalls, rather than merely his own views on the effect of certain specified chemicals; his excellent Paper would have been increased in value; perhaps he would favour the members with the missing information in his reply. Admitting, for the purpose of argument, that the nuisance at the outfalls only existed in sentimental objection, it appeared to him that it would have been true wisdom on the part of the Board of Works, instead of deciding to spend a large sum of money in new works at the present outfalls, to have boldly grappled with the question, and to have decided on carrying the sewage lower down the river, thus finally settling the matter, and to have at once applied efficient chemicals in the existing tanks as a temporary measure. Mr. Dibdin had said (p. 165) that in order to destroy smell sanitarians were limited to practically only two materials, "chloride of lime and permanganic acid," and he said nothing as to the effect of sulphurous acid in the direction wanted. He could speak with great satisfaction of the effect of treating sewage with

Major Flower.

Hanson's black ash waste, a well-known preparation from the refuse of alkali works. He mentioned this in his evidence before the Royal Commission on Metropolitan Sewage Discharge, and if he had then known as much as he now did of its properties and effects, he would have spoken more decidedly about it. It had been used with singularly satisfactory results in the lower parts of the River Lee. Mr. Dibdin had mentioned a fact which Major Flower had often noted, "clearness is no more a sign of purity than is turbidity a sign of foulness." Now, the appearance of the effluent from treatment of sewage by black ash waste was not that of "a good effluent," but its effect upon the river and the bed and banks was remarkable. This was due to chemical changes, to which he would not allude; he would deal with the subject only from the point of view of a practical man accustomed to observe sewage-effluents almost daily for many years. He had recently been informed by a chemical friend that the effect of treating sewage by lime and black ash waste was, that while the objectionable micro-organisms were entirely destroyed by it, much vitality was given to harmless bacteria, which lived by eating up the organic matter, a fact which would be interesting to Dr. Dupré. Mr. Dibdin stated (p. 162) that he had "not the slightest doubt, but that the future treatment of sewage will be a combined chemical and biological one, as suggested elsewhere by Dr. Dupré." Hanson's black ash waste seemed to point to a realization of that idea; the material was the carrier of sulphurous acid. Mr. Dibdin had only given the estimated cost "for chemicals"; the same course was followed by Mr. Hanson in his evidence before the Royal Commission.[1] The cost would be about equal to that mentioned by Mr. Dibdin, column 12, Appendix I, p. 172. Mr. Dibdin had put it at £54,750 per annum; Mr. Hanson at about £50,000 per annum. Of course, those estimates were founded on details which might be modified. In considering the question of "the disposal of the sludge," he thought it was universally admitted that filter-presses seemed to afford the most available way of reducing the moisture. Again, the case was an exceptional one, and even admitting the value of Johnson and Co.'s presses or Clark's radial press, the "cake" must be disposed of somehow. Mr. Dibdin had stated (p. 168) "the furnace appears to be looming in the distance as the ultimate destination of the unwholesome matter." Doubtless, if it were possible to control the dust-bin refuse and road-sweepings, the destructor furnace, as applied so well at Southampton and at

[1] Royal Commission on Metropolitan Sewage Discharge, vol. ii. p. 10.

Major Flower. Ealing, was to be commended. But the case at Barking and at Crossness was exceptional. A series of experiments had recently been carried out at Leyton and on Leyton sludge at Cardiff, having for their object to endeavour to prove that it was possible to burn sewage-sludge without offence and with a profit. He could only quote details of results as given him by an eminent firm of coke-makers. It was proposed by them to treat sewage-cake by "a combination of coking of coal and incineration of sludge-cake." After the fire was started the volatile gases given off in the drying of the cake supplied the carbon wanting in the cake to complete the incineration and to deodorize the offensive gases. The firm stated that "the ammonia escaping during the preliminary drying of the sludge-cake can be collected very economically." Also, that by this process "the coke itself pays the coal and working expenses, and so the cost of incineration per ton of ash does not exceed 6*d*." Thus far for the final disposal of the sludge; but then there was the large cost of the pressing, which was put both by Mr. Dibdin, and by Mr. Santo Crimp, at 2*s*. 6*d*. per ton, irrespective of depreciation and interest on the original outlay; it appeared, however, that half the cost was due to the lime considered to be necessary to be used in the sludge previous to pressing, and to the wear and tear of the cloths at present employed. As to the first item, the aforesaid firm stated confidently that by burning the sludge-cake at high temperature, caustic lime could be produced from the cake itself, which might be used for the pressing, and the cost be much reduced. As to cloths, it was hoped that by the result of a new mode of manufacture, the cost might also be much reduced, and it was believed that a cake might be made at 1*s*. 6*d*. a ton instead of 2*s*. 6*d*. From these figures it might be roughly calculated that 800 tons of sludge per day might be pressed and incinerated for about £30,000 a year. The ash would be of some value, and doubtless would do good on cold clay lands, such as the clay in the Weald of Kent, or upon chalk soils, or as a base for making artificial manures. On p. 167 Mr. Dibdin dismissed the subject very summarily, but with perfect justice and sound argument. "If an inventor has a process by means of which he can more than repay the cost of working expenses, doubtless he will pursue the usual course adopted by business men, and, after obtaining the sludge for nothing and paying working expenses, put a handsome sum in his pocket." "He either fears his fate too much, or his deserts are small, who fails to put it to the touch." Major Flower was informed that there were business men ready to put this matter "to the touch," and relieve the Metropolitan Board of

Works of this part of its heavy task. He did not think the position should be given up as hopeless. Major Flower.

Mr. W. J. Dibdin, in reply upon the discussion, observed that Colonel Jones's first objection was to his Paper being too theoretical. That was a curious criticism, as the whole Paper contained only one proposition not founded on ascertained facts, and that one was a logical deduction from known data. Colonel Jones was of opinion that the fact of 10 tons of chemicals being required daily to supply each gallon of sewage with 1 grain, originated a theory which the Author had never propounded, viz., that the fewer matters taken from the sewage the better. Nowhere could such an idea be found shadowed in any part of the Paper or elsewhere. As many persons seemed to be unaware of the vast quantity of sewage to be dealt with in the case of the Metropolis, he mentioned this simple arithmetical fact in his evidence before the Royal Commission on Metropolitan Sewage Discharge, merely as a useful mental guide in working out results stated in grains per gallon. Its value was well shown by the fact that, if but 1 grain of precipitating matter were added to each gallon of sewage in excess of the quantity actually required, no less than 100 tons of sludge, of 90 per cent. moisture, would have to be disposed of daily by reason of that seemingly unimportant quantity. Thus: 1 grain per gallon was equal to 10 tons daily or 100 tons of 90 per cent. moisture. Colonel Jones's want of appreciation of biological facts was well shown in his remarks on this question. He evidently did not seem to be aware that permanganic acid had not been used previously to any extent in the treatment of sewage because of the expense, and that its adoption now was solely due to the fact that this difficulty had been overcome by the Author's manufacturing operations. Colonel Jones stated that placing the sludge on land to dry was the very thing he proposed to the Royal Commission. Mr. Dibdin did not read his proposal thus, but that he intended to mix a large quantity of earth with the sewage, allow that to settle with the suspended matters, and so accumulate a bed of well-manured soil under flowing water. This was a very different thing to placing wet sludge on the ground and allowing it to lie and putrefy until it dried up. It was true that if circumstances were different; if pressing could be accomplished at a low rate; if farmers would take away the pressed cake, and so on through a variety of ifs, he should prefer not to take the sludge to sea. But where a practical difficulty had to be overcome, practical measures must be adopted. Colonel Jones was wrong in stating that the Author Mr. Dibdin.

Mr. Dibdin. at any time considered the carriage of the sludge to sea absurd. Other systems might have appeared more desirable, but a wise man looked to the possible. He seemed frightened, too, at the possibility of regulating the application of the chemicals to the ever-varying flow of sewage. That was a mere mechanical detail of which engineers of the present day did not require to be informed by a chemist. It would be sufficient to say that this point had received the attention of the proper persons. He further contemplated the possibility of an expense for chemicals for the treatment of the Metropolitan sewage of £268,275 per annum. Why did he not at once contemplate the sum given in column 25, Appendix I, viz., nearly £10,000,000 per annum? The addition of permanganic acid to the effluent during the summer months would involve some £15,000 beyond the £20,805 in column 7. The total cost of the process proposed by Mr. Dibdin, including working expenses and interest on capital, was estimated at £118,000 per annum, as against double, and more than double that sum, which would be involved by the cheapest plan otherwise proposed. Mr. John Jones complained that the country could not afford to throw away any manurial matter. If the country required sewage-sludge the country would take it, especially when it could have it for nothing, but the country would not and did not take it, and it had to be got rid of somehow. After over 3,000 tons had been given away during the past twelve months at Crossness, there was now more than that quantity of sludge lying ready for removal, and only small quantities were being taken away, mainly at the instigation of members and friends of the Metropolitan Board of Works, who were doing all in their power to induce farmers to utilize it. Mr. Jones thought that if farmers would not have it, then the sludge could be made commercially profitable by separating it into its constituent elements. Very good; let manufacturers take it. Where would they find another industry in which the raw material was given to them for nothing? Mr. Sillar asked "Was there any one present who believed that there was no agricultural value in sewage?" He was immediately answered by Mr. Fowler, than whom no one was better able to judge, having at last given up the problem after twenty years' hard work spent in vainly trying to induce the country to adopt Mr. Sillar's views. If Mr. Sillar chose to consider a system which received the full endorsement of the Royal Commission "disgraceful," he was, of course, entitled to his opinion. Mr. Sillar was sorry that the Author had arrived at his conclusion, because many farmers would follow his advice. On p. 168, however, it was expressly stated, that

"Beyond doubt the wants of farmers should be most carefully considered. So long as they remove the sludge from the works, so long should sufficient be pressed to meet their demands." Further evidence of the one-sided manner in which Mr. Sillar had read the Paper was to be found in his next remark as to the Author setting aside all statements hitherto made on the subject. Mr. Sillar applied this to the utilization of the sludge, whereas on turning to p. 158 it would be seen that this remark applied to a totally different question, viz., the partial removal of the dissolved impurities. The Author submitted that the wisdom of starting on an entirely new basis was clearly proved by the results of the special experiments made on this point, as the light thus thrown on the subject was of great help in reconciling the seemingly contradictory results hitherto obtained. Mr. Sillar objected that the only precipitation process in England in which lime was not used had been entirely overlooked by him. Now the A B C process consisted of the use of sulphate of alumina, with a little blood and some charcoal and clay. The Table in Appendix I showed results obtained by the use of alumina, and also of animal charcoal, and proved that while no advantage was to be derived from the use of these substances in the place of lime and iron when properly applied, their cost was far greater. Furthermore, the recent Royal Commission on Metropolitan Sewage Discharge in their second and final Report, p. lviii., stated, with reference to the process of the Native Guano Company: "There appears no evidence of its superiority to others in the resulting effluent. . . . The fact that, although it has been before the public for sixteen years, and has been tried in many places, it is only now adopted in one small town, does not speak in its favour." Again, "That several processes appear to be fairly effective, but that there has been no evidence to satisfy us of the marked superiority of any one in particular." Mr. Sillar quoted a Report by Dr. Tidy and Professor Dewar on the treatment of the Aylesbury sewage, and implied that a similar result would follow in the case of the London sewage. Here, again, Mr. Sillar showed that he had not grasped the contents of the Paper thoroughly. On p. 159 the Author stated "that no practical process of chemical precipitation is capable of removing more than a limited quantity of the oxidizable organic matters in solution in London sewage." And on the same page, "The second portion of the Table gives some results, which will explain the remarkable differences of opinion expressed, by various authorities, as to the percentage reduction of dissolved solids by various processes, when acting on sewage of a different character to that

Mr. Dibdin.

Mr. Dibdin. of London. The sewage used for this purpose was obtained from other sources, and was evidently of such a character, that the oxidizable dissolved solids were readily precipitated by even a small quantity of lime in solution, viz., 5·0 grains per gallon, no less than 52 per cent. being removed. The addition of an iron salt to the limed sewage effected a further reduction of from 9 to 17 per cent., or, in the latter case, a total reduction of the dissolved oxidizable matters of 69 per cent.," and he then referred to the further experiments in corroboration of these results. He had purposely refrained from criticising results obtained by patent processes at isolated places. Mr. Sillar considered that the manurial value of the sludge was neutralized by the addition of lime. Now, what was the character of the manure produced by the Native Guano Company at Crossness in 1872? On p. 11 of the Reports by Sir Joseph Bazalgette and the late Mr. Keates on that company's experimental operations at Crossness, an analysis of the manure so obtained was given, from which it would be seen that only 0·48 per cent. of phosphoric acid was present in the London-derived sewage-manure of the Native Guano Company, while the ammonia was only 0·36 per cent. On turning to his Paper, it would be seen that the pressed sewage-sludge obtained at Crossness by his process contained actually more organic matter and ammonia, and about half as much again phosphoric acid as the celebrated Native Guano Company's London-derived production. The following were the two analyses side by side for comparison,

	Native Guano Company's manure as made at Crossness in 1872.	Pressed Cake at present produced at Crossness.
	Per cent.	Per cent.
Water	26·45	58·06
Organic matter	16·16	16·69
Alkaline salts	0·36	—
Carbonate of lime and magnesia	2·62	7·94
Phosphoric acid	0·48	0·66
Alumina and oxide iron	15·42	4·36
Insoluble siliceous matter	38·51	—
Free lime	—	2·45
Silica	—	8·08
Alkalies and loss	—	1·76
	100·00	100·00
Total nitrogen in the organic matter, calculated as ammonia	0·929	1·060

so that the effect of the lime used by the Author, and objected to by Mr. Sillar, could be at once seen. Dr. Angell seemed to be

under a wrong impression as to his objection to unnecessary agitation in the sewers. The idea intended to be conveyed was that prevention was better than cure. The contrivance of Mr. Baldwin Latham, for straining off the larger solid matters, was far better than breaking them up and afterwards removing portions from the liquid by precipitation. In all other respects he would aerate by all means, and to the greatest extent possible. He admitted that sulphate of alumina removed some matters in solution, but the question was, to what extent? Mr. Bennett seemed not to be aware that an eminent engineer was attached to the staff of the Metropolitan Board of Works, and that the Author was by no means solely responsible for the recommendation to take the sludge to sea. So far as he was concerned the engineers might have all the sludge, as he thought that few chemists would care to interfere with them in the matter. Chemists had tried their best to utilize the foul matter for years past, and were now compelled to admit that they could do but little with it. He had already stated that the Southampton scheme was an admirable one where it could be carried out, and in such cases he would recommend it for adoption, but the circumstances of the Metropolis were so different, that it would be very doubtful if all the authorities interested in the matter would work together to bring about the desired result. The present need was to dispose of a nuisance, and not to wait until more elaborate plans could be got into working order. The scheme was not peculiar to Southampton, although it had been recently brought into prominence in connection with that town. Dr. Tidy's criticisms might be divided into twelve parts, namely: 1st. That Mr. Dibdin, with others, was entirely discredited in matters of fact, as the evidence given by him, and them, before the Royal Commission on Metropolitan Sewage Discharge, was not subsequently borne out by experience under different circumstances; 2nd. A refusal to discuss the question of the quantity of suspended matter in the London sewage; 3rd. An attempted ridicule of the quantity of lime and iron proposed for the treatment of the London sewage; 4th. The implied doubt as to the change of the iron from the ferric to the ferrous state; 5th. A mixture of facts as to the action of the iron and permanganate; 6th. Quotation from Dr. Dupré's evidence in a case totally different to that of the Metropolitan outfalls; 7th. A criticism of the Table, Appendix I; 8th. The cost of the lime; 9th. A statement as to an alleged refusal of the Metropolitan Board to let him have samples of sewage; 10th. A comparison of the effluent from Crossness with sewage taken from the Fleet Sewer; 11th. A misrepresentation of his objection Mr. Dibdin.

Mr. Dibdin. to claptrap statement that because a clear effluent could be produced it must therefore be pure; 12th. Dr. Tidy's certainty that the ratepayers' money was about to be wasted. Dr. Tidy's first, second, sixth, and ninth points were not in any way connected with the subject-matter of the Paper, Mr. Dibdin would therefore deal with them before considering those points more immediately in connection with the subject before the Institution. Dr. Tidy, with many others, had overlooked the fact that from the time the evidence was given before the Royal Commission, the atmospheric conditions had entirely altered. The evidence of the witnesses on behalf of the Metropolitan Board of Works was prepared previously and up to the spring of 1883. On looking at the returns of the Registrar-General for the years 1877 to 1886 it would be seen that the rainfall at Greenwich was as followed:—

	Total Rainfall.	Rainfall during June, July, and August.
	Inches.	Inches.
1876	23·93	3·91
1877	27·41	5·84
1878	28·55	10·26
1879	31·65	13·18
1880	29·07	6·74
1881	25·44	7·80
1882	25·16	6·04
1883	21·98	4·13
1884	17·76	4·65
1885	23·05	3·49
1886	24·10	4·05

In 1885 a depth of 10·16 inches, and in 1886 of 9·25 inches fell in the months of September, October, November, and December. From these returns it would be seen that the circumstances were entirely different after the date of the evidence—a fact which Dr. Tidy failed to take into account. Surely even he would admit that, given from 50 to 300 per cent. more rainfall, a different condition of the river was to be expected. It was generally admitted that the first report of the Commission was by no means an alarmist report. The following quotation from the conclusions of the commission was very different from the report made after the experience of an exceptionally hot summer and low rainfall:—"That it does not appear that hitherto the sewage discharge has had any seriously prejudicial effect on the general healthiness of the neighbouring districts. But that there is evidence of certain evil effects of a minor kind on the health of persons employed on the

river; and that there may reasonably be anxiety on the subject for the future." The witnesses for the Metropolitan Board said that nothing was wanted under the existing circumstances, and they were right on matters of fact. Because a few exceptionally dry summers had for a limited time caused the river to be a nuisance, Dr. Tidy took alarm, and would plunge the ratepayers into an expenditure of millions of money, in a vain and useless attempt to turn the river-water at Barking and Crossness into the condition of drinking-water. Dr. Tidy's second point was his refusal to discuss the quantity of suspended matter in the London sewage. In this he was wise. His statement that the Author had left out the storm-water was incorrect. If he meant that the storm-water discharged from the storm-overflows was not included, he was correct, as Mr. Dibdin's object was to ascertain the quantity in the sewage which arrived at the outfalls under all circumstances, which was generally considered to be what was meant by the suspended matter in London sewage. The storm-overflows might be looked upon for all ordinary purposes as things which would have their way independent of the outfalls, and could not be included in any question of the amount of sludge likely to be derived from the sewage treated at the outfalls, which was the quantity to be considered in connection with the subject of the Paper. Dr. Tidy's sixth point had, so far as it affected Dr. Dupré, been answered by that gentleman. The ninth point was a misrepresentation on the part of Dr. Tidy. The moment he applied to a responsible officer of the Metropolitan Board of Works, he obtained what he wanted, and unlimited permission to have as many samples of sewage as he pleased. Now to deal with Dr. Tidy's serious attempts at criticism. His third point was as to the quantity of lime intended to be put into the sewage by the Metropolitan Board. He ridiculed it, but he did not deny the fact that the matters in suspension were precipitated. Now in Dr. Tidy's evidence given before the Royal Commission, in answer to question 18,529, p. 81, Vol. II. of Minutes of Evidence, he said: "Now the first question is, what is the cause of the nuisance? The nuisance complained of arises in my opinion from the solids in suspension being discharged into the river. I am convinced that if this solid suspended matter was removed the nuisance would be materially diminished, if not entirely prevented. These solid matters amount on an average to 25 grains of dry solid matter per gallon; or, taking the quantity of sewage at 120,000,000 gallons daily, to 200 tons of solids without moisture." Dr. Tidy had recently stated the same thing in stronger terms at the Society Mr. Dibdin.

Mr. Dibdin. of Arts.[1] Therefore, however he might try to hark back, he was bound to admit that in removing the suspended matters the Board would be doing all that was necessary. The particulars of the method were unimportant. Dr. Tidy and others gave evidence before the Commission upon various systems of chemical treatment, and upon those data the Commission estimated that a certain quantity of sludge would be obtained. Now, what were the facts? By treatment of the sewage by only 3·7 grains of lime and 1·0 grain of sulphate of iron the Board obtained, after allowing for the reduced quantity of chemicals added, just the amount of sludge estimated by that Commission. Therefore, having removed what should, in the opinion of the Commission, be removed, as much and no more could be left behind than the Commission contemplated would be left after treatment of the sewage by the best known process. That simple fact could not be explained away. The following statement showed the estimate of the Royal Commission as against the actual results obtained from the treatment of nearly 500,000,000 gallons of sewage at Crossness by means of 3·7 grains of lime and 1·0 grain of protosulphate of iron:—

—	Royal Commission Estimates.	Metropolitan Board's actual results.
	Per day of 150,000,000 Gallons	Per day of 150,000,000 Gallons.
	Tons.	Tons.
Wet sludge as precipitated	4,500	4,620
Reduced to second settlement in special tanks	Not contemplated by Royal Commission.	2,745
Pressed Cake	900	803

The value of Dr. Tidy's criticism was also shown by his statements, repeatedly made, that an effluent could be obtained by chemical means equal in purity to the river-water into which it was to be turned. The experience of the whole country was against that mischievous statement. Dr. Tidy had tried it at place after place, and had never accomplished it. Therefore, on the ground taken by him Mr. Dibdin had a right to argue that Dr. Tidy's future statements on the sewage question were vitiated beyond recall. Dr. Tidy's fourth point was on the change in condition of the iron from a ferric to a ferrous state. Was it not

[1] Journal of the Society of Arts, vol. xxxv. p. 78.

an established fact that in the presence of organic matter ferric oxide was reduced to the ferrous, or protoxide, as Dr. Tidy preferred to call it? This was the admitted cause of the presence of sulphide of iron in mud. Dr. Tidy said he had tried it; but he did not deny it. As to the value of iron in preference to alumina, Dr. Tidy informed the Royal Commission that he obtained "as good an effect by about 6 grains of copperas as . . . . from about 10 grains of sulphate of alumina." But he objected to it because it would turn black. The very action of which he asked for proof! His fifth point was thoroughly absurd. The iron was put in with the lime, and did its work in company with that lime, and was precipitated with the sludge, and no iron was left in the effluent. If an excess of iron were put in he would be correct, but Mr. Dibdin did not propose to put in an excess, and therefore he was incorrect in thinking that the permanganate to be added to the effluent would be interfered with in any way. His seventh point was an attempt to throw discredit upon the Table, Appendix I. Why did he not continue his argument, and carry on the comparison with the lime and alumina? The same argument applied, and with greater force. Take column 16, where 5 grains of lime and 5 grains of sulphate of alumina removed 18 per cent. In column 2, it was shown that 5 grains of lime alone removed 15 per cent. Therefore the alum, his pet precipitant, removed only 3 per cent., or 0·6 per cent. per grain of alum as against 2 per cent. by the iron. Further examination of the Table in the same way would bring out this fact more and more. His eighth point, the cost of lime, was one which Mr. Dibdin would leave him to fight with the lime burners. Whatever might be the actual cost by the time it was landed, stored, slaked, and put into the sewage, mattered not for his present purpose. A unit was taken for comparison, and it served that purpose. His tenth point was the comparison of the effluent from Crossness with a sample of sewage taken from the Fleet Sewer. Mr. Dibdin could well imagine Dr. Tidy's indignation, if such a preposterous thing had been brought up in evidence against himself. He thought he was aware that sewage varied day by day, and hour by hour. With regard to his eleventh point, in which he misrepresented the Author pointing out the mistake made by many (to no little extent on Dr. Tidy's representation), that an effluent was pure because it was clear, bitter experience had brought this error home to so many that he would leave Dr. Tidy's misreading of his statement as not worthy of further notice. The inference from Dr. Tidy's last and twelfth point was, that the Metropolitan Board of Works, in not calling him in for advice, was

Mr. Dibdin.

Mr. Dibdin. doomed to failure. On this point, the action of the Board had nothing to do with the Paper, and required no further remark than that which he had made elsewhere, "We believe we are on the right track, and are doing what is right in the interests of sanitation and the ratepayers." Mr. Maudslay had remarked that "if those who had the power would only try it for London, they would probably obtain the same beneficial result as had been obtained at Southampton." If he had carefully examined the Table, Appendix I, he would have seen that experiments had been made with both alumina and charcoal, with no better results than were obtained by means of lime and iron. It had been stated that alumina and charcoal were the two principal ingredients of porous carbon, so that it would seem that no better results were to be expected from the use of this material than from the other two substances, viz., lime and iron. Mr. Strachan's remarks did not however bear out Mr. Maudslay's ideas. Mr. C. Jones said that sludge consisted almost entirely of carbonaceous material. The analysis of the Crossness sludge given in Appendix III showed that it only contained some 16 per cent. of organic matter. He heard for the first time of Mr. Jones's invitation to Ealing. The facts of the case were simple. If the cost of pressing was prohibitory, as it appeared to be in the Metropolis, what was the use of considering the question of burning it? Mr. Jones did not contend that he could burn the unpressed sludge, but only the pressed. Therefore, if it were decided to carry the sludge to sea, what good would be done by considering a point which could only be arrived at by first doing something which was not intended to be done? The cost of pressing the sludge of the metropolitan sewage was far greater than in many other cases, in consequence of the additional quantity of lime required to be added to it, namely, from 2 to 4 per cent., or from £20,000 to £40,000 per annum; a sum which would in itself go a long way in paying for the transit of the unpressed sludge to sea. No one doubted that small quantities of cake could be burnt without nuisance. It was a question of advisability, and not so much of practicability. By burning, the whole of the value of the sludge, whatever it might be, was absolutely lost; but when it was taken out to sea, it served to manure our fish-fields instead of our corn-fields. This point had been dealt with by Sir J. B. Lawes, and was confirmed by the researches of Dr. Sorby on the support of aquatic life by sewage matters. It was interesting to hear the opinion of Mr. C. Jones that sludge was a thing to be got rid of at the least expense, as it confirmed the opinion given in his Paper. Mr. Mansergh,

Mr. Dibdin.

appeared to think that household deodorization was not practicable. This was one of the matters on which the public required educating. Many people habitually spent large sums in disinfecting materials. If they could only be brought to use a portion of their efforts in deodorizing the sewage of their own establishments effectually by an oxidizing agent, the problem would be solved. The work done by the Metropolitan Board last summer in deodorizing the sewage as it flowed through the main sewers was productive of great benefit. After passing a deodorizing station the sewage was free from nuisance, in many cases for over 2 miles, when the constant addition of foul sewage from the local sewers again rendered it offensive. The results of the experiments made by Mr. Mansergh and Dr. Ashby at Grantham justified his endorsement of Dr. Dupré's forecast. Mr. Mansergh's theory of the cause of the river-water becoming bad in the last year or two was quite in accordance with his latest observations, the nuisance during the past three summers undoubtedly being due to the suspended and not to the dissolved matters freshly discharged. This was a most important question, and one which should be remembered in the event of the river not being all that was desirable during the first summer after the opening of the precipitation works. He did not anticipate the evil being present to such an extent, but it was a contingent one to be borne in mind. He considered that the remarks of Mr. Birch showed very strikingly the uselessness of excessive quantities of chemicals. In reply to this gentleman's question as to the strength of the sewage, he had been careful to treat the sewage at the outfalls in order that it might be perfectly fresh. In order that this might be done, one of Mr. Dibdin's assistants, Mr. G. Thudichum, had when necessary worked all night, and was entitled to no little credit for the completeness of the Table, Appendix I, as the samples represented hourly samples during twenty-four hours, and might be taken as fairly representing the day's flow. They were not all taken on one day, but over a period of some weeks. A great deal more work should be done in this direction; and he hoped that some new light would be thrown upon the matter by further results. The Author would be happy to give Mr. Birch any information in his power. Mr. Baldwin Latham objected to his statements as to the suspended matter in London sewage. Dr. Tidy formerly held the same view as Mr. Latham, but he had now abandoned that position, as shown by his evidence before the second inquiry of the Royal Commission. The results of the

Mr. Dibdin. treatment of the sewage during only ten hours of the day, which was the time during which the Native Guano Company worked, could not be admitted as indicating the average character of the sewage during twenty-four hours. The estimate of 27 grains per gallon was not founded on the southern sewage only, but on that of both sides of the river. He was not responsible for the results of sewage experiments made by other people at other places, and therefore did not wish to dispute the statements of Mr. Latham; but he should like to ask if he used lime in solution? If not, the results were a foregone conclusion. Mr. Latham considered that 10 tons of manganate would be useless for the deodorization of the effluent produced by the means which Mr. Dibdin suggested, and calculated that the quantity of oxygen coming over Teddington weir was some 15 tons per day during the summer of 1884. He thought that if 15 tons of aerial oxygen were insufficient to keep the river in good condition during that season, 10 tons of manganate would be useless. Now what were the true conditions of this problem, which it was evident that even yet Mr. Baldwin Latham had not grasped? In 1884, the river had to deal, besides pollution from other sources, with the whole of the sludge as well as the dissolved matters. When the Metropolitan Board's works were in operation, the worst part of the sewage—the sludge—would be taken out absolutely. Therefore, all the oxygen of the river would be available for the dissolved matters, which would be equivalent to multiplying the available oxygen of the river-water several fold. Moreover, the admitted cause of the nuisance in the river during the summer months, viz., the accumulation of suspended matters, would be done away with. The mere removal of the sludge would doubtless effect such an enormous improvement, that there seemed little likelihood of any danger in future of the river indicating in any way the presence of sewage matters. As a further precaution, however, it was proposed to add a small quantity of chemically active oxygen to the effluent, and so do away with the possible chance of nuisance, by effecting the oxidation of the small quantity of actually putrescent matters left after precipitation. The quantity so proposed to be added was in the form of manganate of soda, of which from ½ to 1½ grain to each gallon would be used. Those quantities were by no means absolute, but approximate; and during a very dry and hot season probably 2 or 3 grains might be added. If the quantity were thus increased to 2 grains per gallon, the total amount of chemically active oxygen which would be thus introduced would be 1 ton per day.

With regard to the question of fish, he had kept living fish for many weeks in water containing one-fifth of its volume of effluent obtained in the manner proposed by him for the treatment of London sewage. Mr. Latham's experience, at Northampton and at other places, confirmed his conclusion that under most circumstances mere chemical precipitation was by itself insufficient. The case of the Metropolis was, however, so different from other places that no comparison could be drawn. With regard to the pressing, he had some experience of centrifugal drying-machines for sludge, but could not join Mr. Latham in his sanguine anticipations. Mr. Melliss agreed that perfect purification could not be attained by chemical means; but he probably failed with the lime and iron experiments for the same reason that Mr. Latham had done, but of neither of these experiments did he know anything. Both of these gentlemen seemed to be of opinion that Mr. Dibdin was wedded in some way to exactly 3·7 grains of lime and 1 grain of protosulphate of iron. These figures had so come out from the calculated quantities used, and had been retained for convenience as indicating the system, but meant nothing more. It would have been better perhaps to have put the word "about" before them. The point was to use sufficient chemicals to do the work, whatever it might be, and no more. Sir Robert Rawlinson had fully confirmed all that he said upon the uselessness of trying to purify sewage completely by chemical treatment. Mr. Dibdin would assure Sir Robert Rawlinson that his estimated expenditure, viz., £2,000 for each million gallons per day, or for the 160,000,000 gallons of London sewage £320,000,000 per annum, was not contemplated; and, as had been shown by his Tables, and the published reports of the Metropolitan Board of Works, was unnecessary, the estimated cost, inclusive of all charges for the treatment of the sewage at the outfalls, being £118,000 per annum. If eventually the remaining portion of the Royal Commission's recommendation, as to carrying the effluent to Hole Haven, or filtering it through land, had to be resorted to, then an additional burden would have to be thrown on the ratepayers; but while there was a reasonable hope that all that was necessary could be accomplished for the comparatively moderate sum stated, he contended that such process ought to be tried before resorting to further enormous expenditure; especially so, when the works involved were only those contemplated by the Commission, and this view the Metropolitan Board of Works had adopted. In so doing the Board was by no means bound to remain satisfied should further measures ultimately appear advisable. He would again Mr. Dibdin.

Mr. Dibdin. repeat what he had so often said, namely, that if the water at Barking and Crossness were to be used for drinking purposes, he would be the last to advocate the admission of any effluent into it, unless that effluent had been first put on suitable land. But the circumstances were so different, and the volume of river-water so large compared with the sewage, that there could be no doubt but that as the river had been able to deal with the whole of the sewage, including the suspended matter, up to within the last few years, so it would be able to deal, with the dissolved matters only, for many years to come. If the proposed system was not entirely satisfactory, no difficulty beyond time and expense would be experienced in carrying out the further recommendations of the Royal Commission; thus, while the Board was proceeding in the right direction, it was at once on the side of economy and efficiency. Mr. Jerram's remarks were of the highest importance, and, he thought, formed one of the most valuable contributions to the discussion. He quite agreed with him in his explanation of the cause of nuisance in many cases. In the use of iron the great point to be attended to was the precipitation of the whole of it. If some portion were allowed to enter a small stream, unpleasant effects would be sure to follow. Mr. Jerram fairly answered Colonel Jones as to the difficulty of regulating the chemicals to the flow of sewage. Dr. Edmunds repeated the idea of Dr. Tidy, as to the action of the iron salt on the permanganate. But let it be supposed that the whole of the 1 grain of protosulphate of iron would be left in the effluent. The quantity of oxygen required to convert the iron from the ferrous to the ferric oxide would be about one-half of that supplied by 1 grain of manganate of soda. Therefore, the undetectable quantity of iron salt, if any, left in the effluent would be without the slightest practical effect on the manganate subsequently added to the clarified liquid. Unfortunately these two doctors differed as to the reoxidation of the iron oxide by the oxygen dissolved in the sewage. Dr. Tidy disagreed, but Dr. Edmunds agreed with him. Dr. Edmunds' advocacy of the A B C system and the claims of the Native Guano Company was a mere repetition of what he recently said before the Society of Arts,[1] and was no new contribution to the question. Mr. Shelford agreed with him as to the advisability of using as small a quantity of chemicals as possible, but objected to the statement that the average London sewage contained only 27 grains of suspended matter. This point had already been answered in reply to Mr.

[1] Journal of the Society of Arts, vol. xxxv. p. 41.

Mr. Dibdin.

Baldwin Latham. Mr. Shelford, however, further asked for the data on which the statement was founded. Mr. Dibdin would refer to his evidence before the Royal Commission, when he gave the results of the examination of samples of sewage collected at the outfalls every four hours, day and night, from the 12th of March to the 16th of May 1883 at Barking, and from the 23rd of March to the 19th of May 1883 at Crossness. Mr. Shelford considered "that the satisfactory solution of the sewage question was almost as far off as ever." Mr. Dibdin could not agree with this opinion. Hitherto the great stumbling block in the way of a proper solution of the difficulty was the interested motives and unfounded statements of patentees, many of whom were absolutely unacquainted with the practical difficulties of the question at the time of their so-called "inventions." If his efforts to tear aside the veil from these various mysterious processes were in any way successful, an enormous stride would have been made. Immediately sanitarians recognized the facts that the power of chemistry in this matter was limited, that sewage-sludge had to be got rid of at the cheapest rate, whether profitable or not, and that common sense was the best guide, a new era in the treatment of sewage would have arisen, and rapid progréss might be anticipated. Mr. Shelford agreed that the carriage of the sludge to sea was, in the present state of knowledge, the readiest way out of the difficulty of relieving the Metropolis. He acknowledged with pleasure the generous support of Dr. Thudichum. Mr. Eachus agreed with his advocacy of household treatment of excrementitious matter. This was a point which had engaged his most serious attention. In the case of the Metropolis it was a big question, but not more so than many others which had been strongly advocated by influential members of the Institution. Some few years ago there was a strong agitation for an additional water-supply, to be used for dietetic purposes only. It was now generally admitted that the present supply was all that was required in that direction. But if there was no longer a necessity for that purer supply, he thought that there was a very strong necessity for a sanitary water-supply. Let each water-closet be supplied only by a special main, which should be charged with a solution of such disinfectant of an oxidizing nature as might be chosen. The same supply should be laid on to urinals, &c. Waste could be prevented by the use of waste-preventer cisterns, such as were now being compulsorily fixed where the companies were laying on a constant supply. The deodorizing substance employed, whatever it might be, should not act as a

Mr. Dibdin. precipitant so as to choke the sewers. The effect would be marvellous. No sewer gases either in house or street, the arrival of the sewage at the point of disposal in a harmless condition, and undoubted benefit to those engaged in or upon the lines of sewers. This idea might at first seem a startling one, but not more so than many others which had taken root and brought forth fruit to the benefit of both the public and those who had taken it up. He firmly believed that some such scheme would be in operation in the not far distant future. Mr. Eachus was under a wrong impression regarding the character of the liquor from the sludge-presses; it was clear and brilliant instead of being black. It was, in fact, a solution of lime strongly charged with dissolved organic matter. He found that it could precipitate a fresh portion of sewage. It would be useless to attempt to re-treat it, as but few matters could be precipitated from it; and those held in solution would have to pass on ultimately with the effluent whether it was attempted to keep them back or not. Mr. Eachus thought that the Metropolitan Board might obtain some 20,000 or 30,000 acres of land at a very low price. Was he not aware that immediately a public body required land it became by some mysterious process "highly elegible building sites," and must be paid for accordingly? Mr. Giles's experience in the Committee Room of the House of Commons, with samples of the effluent proposed to be obtained by Dr. Tidy from the Lower Thames Valley Main Drainage Works, intended to be established at Mortlake, was both amusing and instructive, and a curious commentary on Dr. Tidy's declared intention of producing an effluent as pure as the river-water into which it was to be discharged. Mr. Giles joined with the strongly swelling tide of opinion as to the advisability of taking the sludge to sea. Dr. Stevenson asked for the results of experience on an extensive scale of the process proposed by Mr. Dibdin for the London sewage. The precise plan proposed for the London sewage, which was to be discharged into a large volume of river-water, had answered completely in the case of the River Soar, into which at times only sewage effluent was flowing, after all other plans had failed, including Dr. Tidy's lime, alum, iron, black ash waste, porous carbon, &c. Dr. Stevenson supported his advocacy of dissolved instead of undissolved lime. He had not been able to detect any protosalt of iron in the effluent obtained by the addition of only 1 grain of the sulphate to a sewage charged with 3·7 grains of dissolved lime. Dr. Stevenson joined with him in his statement as to the oxygen-carrying power of iron salts; and

as might have been expected from his position of member of the recent Royal Commission, agreed with the suggestion of taking the sludge to sea. Mr. Lloyd thought that the sludge was practically useless, and showed that calculations of the manurial value of sewage-sludge from its percentage composition, as far as the phosphoric acid and nitrogen were concerned, were useless. In this he agreed with him, and also in the proposition that in view of the expense of getting the stuff to the farm, the sludge, whether pressed, dried, or wet, was not worth the having. Mr. Lloyd, as an agricultural chemist, agreed with his proposal to use as small a quantity of chemicals as possible, as thereby the effluent, where used for irrigation, would be more valuable than if highly charged with large quantities of injurious chemicals. Sir John Coode did not seem to be afraid of Mr. Sillar's term "disgraceful," as he was jealous to claim the credit of the proposal to take the sludge to sea for the Royal Commission. Major Flower saw Canvey Island in the distance, and seemed to think it the only solution as regarded the Lee difficulty. As all the Lee Valley sewage was eventually turned into the Thames near Blackwall, and, no doubt, contributed in no small degree to the condition of the river in that locality during the last three summers, Mr. Dibdin agreed that it would be better to divert the sewage from that stream; but in this proposition he saw no necessity for taking it all the way to Canvey Island. So far as the disposal of the Lee sewage was concerned, there was no reason why, after the construction of the proper sewers, &c., the whole of it should not be treated at Barking, and thus relieve Blackwall and the reaches above from this great nuisance, and the present Metropolitan outfalls from the reproach of being the cause of a nuisance for which there were so many other sources. Major Flower should have carefully studied the Paper instead of looking through it merely to see how far "black ash waste" was referred to. He had no desire to criticise patent schemes. If, however, Major Flower wanted information on that subject he would refer him to Mr. Gordon's experience at Leicester. He also considered that the Metropolitan Board would have exhibited true wisdom in what practically would have amounted to spending some £4,000,000 instead of only £750,000 in working expenses, and in constructing works which would occupy some six or seven years before they could come into operation, instead of eighteen months, as by the system adopted. He was, of course, entitled to his opinion; but Mr. Dibdin could not agree with him. Major Flower next considered at full length the advantages of black ash Mr. Dibdin.

Mr. Dibdin. waste, and stated that the active agent in this substance was the sulphurous acid. To this he could only reply that if he required sulphurous acid he would buy, at one-half the price, a substance which contained only a few per cent. of that material in an available condition. Major Flower also asserted that he had stated that the cost of pressing the sludge was 2*s.* 6*d.* per ton. This was a mistake. On p. 167 he said, "Evidence has been put forward in numerous Papers that the cost of pressing is about 2*s.* 6*d.* per ton." He declined to take the responsibility of that statement, as it was not borne out by his experience; but he was willing to make allowances for exceptional circumstances. He was glad to hear that there were business men ready to relieve the Metropolitan Board of the task of disposing of the sludge by a remunerative method. He promised them all the support in his power.

Mr. Crimp. Mr. W. SANTO CRIMP, in reply to the discussion, proposed to confine his remarks solely to the criticisms on the question of sludge disposal. Much dogmatism had been displayed by many speakers, not only with regard to sewage-treatment, but also with respect to the manurial value of sewage and its sludge. On one side there were those who claimed an extreme value for the manurial properties of sludge; on the other side, those who said that it was valueless. Two systems of sludge disposal had been brought prominently forward, namely, those of Southampton and of Ealing. The well-known Birmingham method was also mentioned. With regard to Southampton, it was unfortunate that all the facts were not presented, because, in the absence of full details, erroneous conclusions were likely to be arrived at; in a lesser degree this was also true of Ealing. In a report of recent date, Mr. Bennett stated that the sewage at the platform, or western, outfall, only was treated; the volume was said to be 500,000 gallons per day; the number of persons contributing the sewage was thirteen thousand, whilst the sludge produced amounted to 3 tons per day. That quantity of normal sludge contained 6 cwt. of dry solids; the yield, therefore, was at the rate of 9 grains only per gallon. Of these 9 grains, 4 grains had been added to the sewage as an insoluble precipitant—porous carbon—leaving 5 grains per gallon only as the amount of solid matter precipitated from the sewage. The quantity of sludge, therefore, dealt with was extremely small, and he was not surprised to hear that, even after the ancient method of mixing ashes, street-sweepings, or other absorbent, had been applied, there was no difficulty in disposing of it. Let all the sewage of Southampton be treated, all the solids in suspension precipitated, and then try the method, which was said to be, and

indeed might be, successful, on a small scale, and he ventured to say, that the system would be unworkable. Mr. Bennett's suggestion, as to the application of this system to the disposal of the whole of the refuse of London, was not new; it had been fully discussed by Mr. Booth Scott, M. Inst. C.E., and all the details of the scheme were given in one of the International Health Exhibition Handbooks, that on "Cleansing Streets and Ways in the Metropolis and large Cities" (W. Booth Scott, 1884). With regard to Ealing, he regretted that Mr. Jones had not stated the quantity of sludge actually burnt in the destructors. It should also be clearly understood, that before the sludge was burned it was pumped into large tanks, and there ashes were added and the mixture was exposed until sufficiently solidified to admit of its being dug out and placed in the furnaces. It was, indeed, up to this point, precisely similar to the system which it was found imperative to abandon at Wimbledon, in consequence of the foul smells generated. Another point, which should be mentioned, was that in summer myriads of flies bred in the sludge pits; was it nothing, from a sanitary point of view, that these insects should emerge from this mass of gruesome filth and fly to the nearest house, there to crawl over and into their food? He had seen the ceilings of houses, situated near the Wimbledon Sewage-works, at the time when this system was in operation, literally black with these pests. The formula, "sludge is a thing to be got rid of," had been freely adopted, and to this he would add, it must be got rid of quickly; and whether it was cast into the sea, or converted into an inoffensive material by means of machinery, or dug into the ground as at Birmingham, it might be said to be "got rid off," provided that these operations were quickly and properly conducted. Mr. Baldwin Latham adverted to the expense of pressing, and to the desirability of reducing this expense; too much must not, however, be expected from the suggested substitution of direct-acting pumps for the pneumatic system, because, if the details of the cost of pressing were examined, it would be observed that out of a total cost of 2*s.* 6*d.* per ton, fuel amounted to 3*d.* only, and this was the only item in which a saving could be effected by the adoption of direct-acting pumps. Mr. G. E. Eachus fell into a strange series of errors when, in alluding to the filter-press, he said, "it laboured under the great disadvantage, that it squeezed out a liquid which was a black and foul one, and produced a manure which was of no value;" whilst a little later on he said that, "according to the chemicals used, the sludge must have more or less value for different crops." In the experiments of Dr. Munro and his own, the dried and Mr. Crimp.

Mr Crimp. powdered sludge gave the best results; whilst the statement, as to the nature of the liquid from the presses, was entirely erroneous, for, so far from being black, it was transparent, and, indeed, exactly resembled in appearance very light-coloured urine. An extraordinary feature of Mr. Eachus's remarks was the statement that, after taking the solids out of the sewage in the tanks, they were afterwards admitted to the distributing pipes, to be carried with the effluent water to different parts of the farm! He had no hesitation in saying that such a system would not be tolerated at Wimbledon for a single day. Mr. E. J. Lloyd endeavoured to prove that, from a chemist's point of view, sewage-sludge ought not to contain any valuable manurial properties, and that other manures were therefore preferable. To this he would reply that Colonel Jones stated "that he had been using air-dried sludge side by side with farmyard manure, on similar land, for fifteen successive years, without, as a rule, being able to detect any great difference in the resulting crops." Dr. Munro had also proved by experiments that the sludge did contain manurial properties to the degree stated by him; and by his own experiments he had proved that, in the case of four crops out of the five experimented upon, the sludge was superior to farmyard manure. At Salisbury, no difficulty was experienced in obtaining 4*s*. per ton for all the pressed cake, the sewage works being situated in an agricultural district. The question was scarcely affected by the statement, that "farmyard manure was made upon the spot"—*i.e.*, where required on the farm; because, in consequence of the universal and ever-increasing use of machinery for performing farming operations, fewer horses were kept by farmers than formerly, and the farmer must therefore buy more manure, and the manure he would buy was that which to him was the cheapest. In the suburbs of large towns, sewage-sludge would naturally have a less market value than elsewhere, because of the glut of stable and other low-grade manures constantly produced in such towns, which must, to a large extent, be disposed of near the place of production. The market gardeners took their produce in wagons to the towns, and brought them back, laden with these manures. For this reason, and also in consequence of the difficulties of pressing London sludge, unless an excessive quantity of lime was used, as mentioned by Mr. Dibdin, he agreed with those who thought that the best mode of disposing of the London sludge was to take it to sea. At Wimbledon, filter-presses were erected, not to manufacture a manure, but to remedy a nuisance; but, admitting the sludge to be a manure, its market value would depend almost entirely on the locality where it was pro-

duced. In conclusion, while he fully agreed that other methods of sludge-disposal were in successful operation, his opinion, as to the suitability of the filter-press for the treatment of sewage-sludge, had been endorsed by several eminent authorities, who joined in the discussion. He did not for one moment recommend its universal adoption; for that system of disposal was the best, which most fully met all the requirements of each particular case. Mr. Crimp.

Correspondence.

Mr. W. Astrop explained his sludge-drying process at Walthamstow. Sludge containing 95 per cent. of water was pumped to the machine, and was then run into a tank fitted with a number of revolving fine wire-gauze drums, to which were fixed exhausters, with a fall of about 12 feet to the outlet. This maintained sufficient vacuum to separate about 55 to 60 per cent. of the water from the sewage, which was then in a thick, pasty condition. It was now run over a fine wire gauze, 8 feet wide by 24 feet long, over vacuum boxes, at the rate of about 30 feet per minute; it next passed through a series of squeeze-rolls, which had the effect of reducing it to a thin cake; and from thence to the floor below into a cylindrical revolving wire-cage. This cage was subjected to a current of dry air, at a temperature of about 90°, from a Blackman's air-propeller, at the rate of 26,000 cubic feet per minute, the effect of which was that, as the solid matter dried, it was sifted through the cage, and carried to the lower end by an Archimedean screw, when an elevator placed it in a sack as a fine dry powder. Mr. Astrop.

When the sewage was thus treated, quickly and while fresh, it had considerable market value as a manure. About 100 tons of sludge could be treated in three hours at a cost of about 3*s.* 6*d.* per ton of dry powder; but with a little alteration in the machinery, namely, increasing the supply and dimensions of the gauze-drums, the same result could be produced in one hour at a far less cost.

Mr. F. R. Conder remarked that it seemed to be assumed that the foul semi-fluid called sludge was a necessary product of the treatment of sewage. Such an assumption was entirely opposed to fact. Sludge was produced by the mixture of lime or clay with sewage. These materials, acting at first as mechanical precipitants, clarified sewage with a rapidity that had led to their Mr. Conder.

Mr. Conder. frequent adoption. But they prevented that subsidence of the suspended matters into a true precipitate, which occurred in untreated sewage, if sufficient time was allowed for settlement. The time required was, indeed, so long as to render this simple mode of treatment generally unavailable. But the sewage-mud thus obtained was a far more manageable substance than sludge. The latter contained, in addition to the undefecated matter thrown down, and to a portion of the precipitant, from 80 to 90 per cent. of water. The removal of this water could only be effected at a great expense, which Mr. Crimp put at 3*s.* 6*d.* per ton of partly dried sludge, still containing 50 per cent. of water. The cost involved by the production of sludge might be illustrated by the two very different instances of Birmingham and Coventry. At Birmingham, where the sewage was very strong, containing more than 115 grains of foreign matter in the gallon, the lime process removed 3¾ tons of matter from a million gallons of sewage. The result was 31 tons 19 cwt. of sludge. At Coventry, where the sewage was about half the above strength, treatment with lime and salts of alumina removed rather less than a ton of foreign matter from a million gallons of sewage; and the result was 12½ tons of sludge. Mr. Dibdin truly stated that "the object to be gained is the destruction of the sewage matters with the greatest rapidity possible." This was the direct opposite to the plan of aggregating them in sludge. This object Mr. Conder had effected, to the great satisfaction of the local authorities, where his process had been applied. In addition to work, both in the laboratory and in the sewers, at Guildford and at Stratford-at-Bow, at both which places the process employed had produced a pure effluent and a deposit free from associated water, the sewage of the Chichester Barracks was now being treated by the War Department under his supervision. For upwards of six months a pure effluent had issued unintermittently from the barrack-sewers, the discharge from which had previously given much trouble. He had prepared the two subjoined Tables, showing the results of his process compared with those of precipitation and of irrigation. The analyses of the Government chemists demonstrated that the effluent was well up to the severe standard fixed by the Fifth Report of the Rivers Pollution Commission. The precipitate dried readily in the air. It contains, when air-dried, 28·7 per cent. of organic and volatile matter; but only 0·388 per cent. of organic nitrogen, and 0·25 per cent. of phosphate of lime; and was thus quite inoffensive. If the result of the application of his process to the sewage of London should prove to be as effective

as in the three cases cited (and the Stratford sewage was an unusually foul specimen of metropolitan sewage), the million tons of sludge which it was now proposed annually to manufacture, Mr. Condor.

TREATMENT of SEWAGE. COMPARATIVE RESULTS.

Locality.	Sewage. Matter in			Effluent. Matter in			Removed. Matter in		
	Suspension.	Solution.	Total.	Suspension.	Solution.	Total.	Suspension.	Solution.	Total.
	Grains per Gallon.			Grains per Gallon.			Per cent.		
2 towns: iron process	15·59	42·70	57·29	1·72	34·18	35·95	88	20·0	37·67
5 towns: weak sewage	5·83	36·51	42·34	0·22	39·18	39·40	96	Increased.	6·30
6 towns: strong sewage	71·67	62·56	134·23	5·66	62·95	68·61	92	„	48·9
8 towns: irrigation.	12·18	55·44	67·62	1·03	49·05	50·08	93	9·6	26·0
12 towns: precipitation.	49·70	52·52	102·22	4·02	55·50	59·52	91	Increased.	41·6
25 towns: various	32·99	48·87	81·86	..	..	52·77	..	..	35·6

TREATMENT of SEWAGE. PURITY of EFFLUENT.

Foreign Matter in Effluent.	River Pollution: Commissioners' Standard.	Mean of Five Towns: Lime and Irrigation.	Chichester Barracks: Iron Process.	Remarks.
	Grains per Gallon.	Grains per Gallon.	Grains per Gallon.	
In Suspension.				
Dry organic matter . . .	0·7	max. 0·36	0·70	The time from applying the disinfectant to the sewage to taking the samples at Chichester was four minutes. From six to twenty-four hours elapsed in the other cases. After a brief subsidence the whole of the matter in suspension was removed by the iron process.
Dry mineral matter . . .	2·1	max. 0·88	0·75	
In Solution.				
Organic carbon	1·4	1·27	0·14	
Organic ammonia . . .	0·26	0·27	0·05	
Acidity	0·002	..	0·00	
Alkalinity	0·001	..	0·00	
Total foreign matter in sewage	..	42·34	41·88	
„ „ removed	..	3·66	25·20	

would be replaced by about a tenth part of that quantity of a manageable silt, and the pollution of the Thames would be at an end.

Mr. Denton. Mr. J. Bailey Denton held that the Paper of Mr. Dibdin, instead of advancing useful chemical knowledge in connection with engineering, could only be received, in spite of the "reserved" concurrence of four eminent chemists, as a scientific enigma; for while Mr. Dibdin, and the chemists referred to, recommended, on the 27th of October, 1885, the application of 3·7 grains of lime, and 1 grain of sulphate of iron per gallon of sewage as a means of cleansing the sewage of the Metropolis, the Engineer of the Metropolitan Board, who had joined the Chemist in his report of the 17th of November, 1884, did, in his more recent evidence before the Committee on Rivers Pollution (River Lee), recommend as much as 10 grains of lime and 8 grains of sulphate of alumina per gallon, the cost of which would be between nine and ten times as much as that of the chemicals prescribed by Mr. Dibdin and the four chemists. He made these remarks after thirty-five years' continued study of the subject of Mr. Dibdin's Paper[1]—a Paper evidently put forth as a justification of an expenditure on extended tank-works at the present outfalls, which, beginning with an outlay of £406,000 at Barking, could not be completed if Crossness was to be treated on the same lines as Barking, under an aggregate outlay, it might fairly be assumed, of £1,000,000, involving an annual charge of upwards of £40,000. This outlay appeared to all who preferred the matured views of Lord Bramwell, and his colleagues of the Royal Commission on Metropolitan Sewage Discharge, to the preconceived yet pertinaceous ideas of the Metropolitan Board, to be absolute waste, for there were few persons who did not believe that these tanks would be superseded by the extension of the outfall sewers to a point lower down the river. He would particularly point to the fact that the portion of the Thames which was still to be made the receptacle of the Metropolitan sewage, after it had undergone the partial and experimental treatment proposed by Mr. Dibdin, was, as nearly as possible, midway between London Bridge and the new Tilbury Docks. Within this distance there existed important docks, which must necessarily be kept filled with diluted sewage so long as the City of London, the Port Sanitary Authority, and the Thames Conservancy Board, were overruled by the Metropolitan Board of Works. He would remind his fellow members that nothing had done more to exalt the character of the British engineer in the eyes of the world than the dock works on the Thames, and this led him to urge the necessity for engineers doing everything

[1] Minutes of Proceedings Inst. C.E. vol. xxiv. p. 516.

possible to secure the purification of the river, and to prevent a malarial condition of the water on which floated the ships of all nations. The Royal Commission to which he had referred, in the conclusions arrived at in their First Report, stated, "That in hot and dry weather there is serious nuisance and inconvenience, extending to a considerable distance both below and above the outfalls, from the foul state of the water consequent on the sewage discharge. The smell is very offensive . . . . for these reasons the river is not, at times, in the state in which such an important highway to a great capital, carrying so large a traffic, ought to be."[1] Was it likely that 3·7 grains of lime and 1 grain of sulphate of iron would rectify this condition of things? Upon that question he should like to state that it had recently fallen to his lot, while advising the City of Manchester on its sewerage system and the disposal of its sewage, to investigate generally the treatment of sewage by chemical precipitation, as practised in the principal towns in the North of England. In the midst of much that was sound and satisfactory, he had drawn this deduction, namely, that whenever the sewage of a town was swollen by rain beyond its normal dry-weather quantity, all tank arrangements ceased to be satisfactory; and further, that if regard were had to those instances which were accepted as patterns of chemical treatment, it would be found that as much as 1 ton of lime per million gallons of sewage was used. Thus, if the outflow from the Metropolis was 156,800,000 gallons, as assumed by Mr. Dibdin, to be increased by the sewage from the lower Lee Valley to 170,000,000 or 184,000,000 gallons, and further augmented, as population increased, to above 200,000,000 gallons, and the cheapest kind of chemical precipitant —lime—were used, at least £200 per day, or £73,000 a year, would be required in place of the £31,000 per annum which looked so tempting in Mr. Dibdin's Paper. If to this £73,000 were added the cost of labour in mixing the chemicals and in lifting the sludge into vessels to transport it to sea, together with the cost attending such transport, and interest on the £1,000,000 of capital to be expended at the outfalls, the annual outlay estimated by the Royal Commission as the cost of treatment at the present outfalls (£200,000) would be readily reached. But the River Thames would still remain the recipient of the liquid sewage of the Metropolis, little, if at all, mitigated in character by the 3·7 grains of lime and 1 grain of iron. With respect to the evils that would attend the emptying of barges of sewage into the Mr. Denton.

[1] First Report of the Commissioners, p. lxvii.

Mr. Denton. sea near the Nore, he might state that in 1882 he had been called upon to report on the sanitary condition of Brighton, when he was much impressed with the effect of discharging collected sewage into the sea at each tide from the main outlet. He thought it right to express his opinion that the several watering-places on the Kentish coast, now the health-resorts of a large number of Londoners, would suffer from the abuse with which they were threatened by the Metropolitan Board of Works. He would briefly state what, in association with Lieut.-Col. Jones, V.C., he had found could be done with the sewage of London beyond Hole Haven Creek, the spot selected by the Royal Commission as the nearest point to the Metropolis at which the liquid sewage, after separation from the solid, might be discharged. The sewage from Barking and Crossness might be taken in its present condition to Canvey Island, immediately beyond Hole Haven, by the conduit proposed by Sir Joseph Bazalgette for Thames Haven, and there dealt with by utilizing the sludge mixed with earths of a most favourable character, existing close at hand, to raise its surface, which was now 6 feet 6 inches below high-water spring-tides, at the same time cleansing the liquid by intermittent filtration through soil automatically. He was prepared to prove that this could be done at much less cost than that to which the ratepayers of the Metropolis were now being pledged by the Metropolitan Board of Works, with this very important difference, that the whole of the sewage would be removed from the Thames, thus freeing the river entirely from pollution; whilst, as he had just pointed out, the scheme of the Metropolitan Board of Works would leave it little, if at all, improved.

Mr. Gordon. Mr. J. Gordon had been particularly struck with Mr. Dibdin's demonstration of the solubility of a portion of the suspended matters in sewage by lime, proving, as it apparently did, that a clear effluent from the lime process was at the expense of its being chemically impurer than a less clear effluent, which probably accounted, in some measure, in years past, for difficulties experienced in the River Soar. Mr. Dibdin drew attention also to the increased difficulty of removing soluble organic matters, when diffused in a large volume of water than when dissolved in a small volume. This appeared to account for the different results obtained from the application of the same dose of chemicals, which might be found to answer in one town not being satisfactory in another; and this was the experience of Leicester. For whilst in 1884 the use of sulphate of alumina and sulphate of iron was adopted in addition to lime, in the proportions laid down

by the chemists acting on behalf of the promoters of the Upper Thames Valley Drainage Scheme, and as was then practised at Chiswick and one or two other places, it was soon found necessary to increase the relative proportions of the chemicals, with the exception of sulphate of iron, which was reduced, in order to produce a clearer effluent than before by the use of lime alone. It had not been possible to obtain an effluent satisfactory to the eye with the proportions laid down for the Thames Valley; and when the chemicals were increased so as to produce a clear effluent, Dr. Tidy seemed to think that they were more than were requisite. When Mr. Gordon added, however, that there were more than 8,000,000 gallons of sewage to be pumped daily at Leicester, and that the population was only one hundred and thirty-five thousand, with a water-supply of 21 gallons per head, it would be seen, notwithstanding large manufacturing contributions, in many cases from wells, that the sewage proper was largely augmented by subsoil water, which, together with the deep changing colour of the dyes in the sewage, might account for the increased chemicals requisite, the proportions having been on the average 10 grains of lime, 7 grains of sulphate of alumina, and 1 grain of sulphate of iron, an additional amount of the latter up to 2 grains per gallon having been found to blacken the vegetation on the banks of the river. Mr. Dibdin's Paper referred to charcoal as of no utility whatever for the purification of sewage. This was at variance with the experience so loudly proclaimed to the public by the treatment of the sewage from about thirteen thousand people at Southampton. It was singular, however, that the Porous Carbon Company, to whom he offered every facility to prove the efficacy of carbon in Leicester, with the view to its adoption if successful, had utterly failed under the direct superintendence of their Advising Chemist, Dr. Angell, to produce any appreciable effect upon the sewage of that town. He was prepared to make every possible allowance for a first experiment, and its being carried on with somewhat primitive arrangements, and even for the belief of the Company that carbon could scarcely be expected to act so well in the existing tanks as in those where the sewage could be treated in a quiescent state; but in view of the correspondence on the subject, he thought the advocates of that material for sewage-treatment owed a much more satisfactory explanation than any they had yet offered, of the reasons for their non-perseverance at Leicester under such conditions and encouragement as he had described. He did not find that Mr. Dibdin had experimented on what was known as black ash waste (soda), and which had been tried in several places through Mr. Gordon.

Mr. Gordon. the advocacy of Mr. Hanson, and was now in use at Leyton, and said to be giving good results. He had given this waste product a fair trial, from the 5th of November, 1884, to the 11th of February, 1885, and came to the conclusion that it was of very little value, but he should have been glad if Mr. Dibdin had included it in his experiments. With regard to the further treatment of an effluent from precipitation works in the absence of land, he was able to bear testimony to the satisfactory results obtained, on the advice of Mr. Dibdin, in applying permanganate of soda with sulphuric acid, as at the Metropolitan outfalls, to the Leicester effluent, and, in fact, to a disinfection of the River Soar below Leicester; for, notwithstanding the use of sulphate of alumina and sulphate of iron, in addition to lime, in 1884 and 1885, complaints became loud again in July of the latter year as to the condition of the River Soar. When he stated, however, that at that time the quantity of water flowing in the river above the sewage outfall was reduced to 400 cubic feet per minute, and that the average flow of sewage effluent poured into it was, and still remained, about 944 cubic feet per minute, or nearly two and a half times that of the river-water; whilst the maximum sewage flow at certain hours of the day reached 1,333 cubic feet, or over three times that of the flow of river, it would be readily understood how exceptional were the conditions at Leicester, and how difficult it was to obtain a satisfactory effluent by the chemical system alone. If the river had a good fall, or, still better, if it were a mountain stream, he did not suppose, even with so small a quantity of water, there would have been any difficulty, as the aeration of the effluent would have sufficed to further purify it. In the Leicester case, however, the river, which was canalized, consisted of a series of elongated ponds about 1½ mile each in length, with a surface velocity in the summer months, due chiefly to the sewage effluent, of ⅓ foot per second. Add to this the fact that during the summer of 1886, for about eight to ten weeks, there was no water flowing over the weirs of the river above the sewage outfall, and that none flowed down it, excepting when a boat passed through the locks, and that water had to be let down from the canal reservoirs to carry on the traffic, and it would be readily understood how acute and intensified the conditions became. The application of from 1 grain to 1¼ grain of permanganate of soda, with about ⅔ grain of sulphuric acid, per gallon to the effluent before it passed into the river practically stopped further decomposition in the river, and satisfied the complaining local authorities. Up to that time it had not been possible, however varied the proportions,

with any other chemicals to effect so large a measure of relief as with the permanganate, and he felt very grateful to Mr. Dibdin for having in 1885 afforded so much information and assistance when he visited the Crossness and Barking outfalls. One objection to the use of permanganate of soda in 1885 was its high price, but as a set-off he found he could dispense with alumina and iron, and effect the clarification of the sewage by lime alone, about 16 grains per gallon being used. The cheapness of manganate of soda in 1886 enabled him, however, to effect, at a cost not exceeding £1 14*s.* per 1,000,000 gallons, that which he had been unable to achieve before at a cost of £2 7*s.* 6*d.* per 1,000,000 gallons by the use of lime, alumina, and sulphate of iron. He must not, however, be understood to advocate such a system of after-treatment of the effluent, excepting under such circumstances as had been set forth by Mr. Dibdin, where land was not available, and under such conditions as he had described as existing at Leicester, which he believed to be the most exceptional in the kingdom. The use of the permanganate of soda would be continued until the proposed broad irrigation works on 1,375 acres of land were accomplished, although he thought that all that was necessary could have been effected by the lime process, with a sufficient quantity of land in the valley of the Soar for the further purification of the effluent. With regard to the sewage-sludge difficulty, he agreed that if the sludge could be pressed into one-fifth of its original bulk in the wet state by the various presses now in the market at a reasonable cost, and so long as there was any demand for it in that form, it ought to be done to avoid the nuisance of large accumulations of wet sludge being air dried. He had investigated this matter in 1884, and was prepared to recommend an expenditure of about £6,000 for the establishment of presses for the Leicester Works as a fair trial of that method, in consequence of the large accumulations about the works, which had reached 46,000 cubic yards of air-dried sludge, notwithstanding an attempt to induce people to take it for nothing, and even to assist them in loading their boats, &c. The cost of pressing sludge was, however, very much misunderstood two and a half years ago; it had proved much more expensive than was then anticipated. The quantity of sludge resulting from sewage treatment on the chemical system seemed also to have been considerably underestimated in various places, and varied even now in a degree, which could only be explained by local conditions. In Birmingham, the quantity of wet sludge was equal to about 33 tons per 1,000,000 gallons, whilst in Leicester it ranged from 21 to 29 tons per 1,000,000 gallons, and reached

Mr. Gordon.

Mr. Gordon. the high figure of 50 tons per 1,000,000 gallons at Chiswick. Birmingham was almost purely a pail-closeted town, the number of water-closets being very small in proportion to the number of pails. In Leicester, on the contrary, the proportions were water-closets two-thirds, to pails one-third, but the subsoil water here was fully equal to the water-supply from all sources, whilst at Chiswick it formed only one-fourth of the sewage pumped. Where land was available, it seemed to him that the Birmingham system of digging the sludge into the land was an exceedingly good one. He could not believe that the Ealing system of mixing the sludge with ashes and town-refuse, with the object of partly drying it and then burning it in a destructor, was practicable on a large scale, although he thought great credit was due to Mr. Jones for first starting the idea and putting it into practical shape. For large centres of population, pressing the sludge, and then cremating it in this way, might be the best method of getting rid of it in all respects save one, namely that of cost. For London, however, he could not but think the Metropolitan Board was in the right in attempting to deal with the sewage in a manner which seemed to be within the range of practicability; and in combination with the precipitating system to inaugurate the transport of wet sludge direct to sea, inasmuch as the difficulty of dealing with it in any other way by finding suitable land, or pressing it into a smaller bulk, to facilitate its transport, sale or otherwise, would still be very great, and attended with greater expense than taking it to sea.

Mr. Gower. Mr. C. F. Gower said it would be interesting to know what would be the cost of the proposed sludge vessels, and the working expenses of conveying the 3,000 tons of liquid sludge daily from the metropolitan outfalls, and discharging it into the sea, several miles from the coast. Such information would afford a basis for comparison between the cost of sending the sludge so great a distance, in order to discharge it at sea, and of utilizing it for raising low-lying land contiguous to the river, where the distance and consequent cost of transport would be much less.

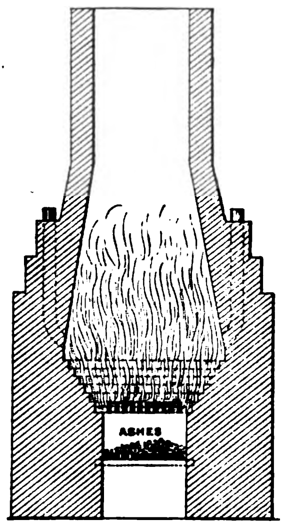
With reference to Mr. Crimp's Paper, it would seem that the liquid pressed out by the sludge-presses, and probably containing much of the organic and other constituents precipitated from the sewage by chemical action, ought not, in accordance with true economic principles, to be returned again into the tanks, so as to add to the cost and difficulty of precipitation, and of obtaining a proper effluent. He should be glad if Mr. Crimp would explain how this liquid was best dealt with, and whether in his experience he had found it to have any value as a fertilizing agent?

Mr. A. JACOB thought that the disposal of sewage-sludge by burning had not received the consideration that it was entitled to, and he believed that, even under unfavourable conditions, the plan of cremation would be as convenient and as little expensive as any of the expedients that had been suggested. About two and a half years ago he commenced disposing of the sludge at the Salford Sewage-works by burning it. The sewage was treated by quicklime, on the continuous-flow principle; 1 ton of Buxton lime being used to every 1,000,000 gallons of sewage treated. During the past three years about 4,000,000 gallons per day had been treated at the works. When the tanks had to be emptied, the supernatant water, which was free from suspended matter, was first drawn off, and was run into the subsoil drains, which delivered it into the River Irwell. The sludge was then allowed to pass out into shallow pits, which had been dug in some low ground below the level of the precipitating tanks. Whilst in these sludge-pits, some of the water evaporated, and a considerable portion filtered through the soil, and so passed into the sub-soil drains. The time required to bring the sludge to the proper consistency varied with the state of the weather, as during winter the evaporation was but trifling, and there was generally a heavier rainfall than in the summer. The difference was, however, not so great as to render the management of the sludge during winter much more troublesome than in summer. He had erected six small kilns (Figs. 1 and 2, p. 284). These kilns were somewhat similar in vertical section to an ordinary lime-kiln, but they had a short vertical flue or shaft, which produced a certain amount of draught. There were openings near the base of the shaft, at A, through which the semi-solid sludge was introduced into the kiln, and there were simple gratings at the bottom, through which the ash could be raked out. The sludge was sufficiently dry for burning when it could be lifted on a shovel, and in this state it contained about 80 per cent. of water. It was a matter of some surprise that the material should burn freely, containing so much moisture as it did; but, as a matter of fact, it did burn freely, and without any addition of coal or other fuel. When the kilns were first lighted, a small quantity of slack was employed, for the purpose of kindling the fire; but afterwards, if due attention was paid to the furnace, it went on burning freely day after day. Each kiln burnt 3 tons daily of the semi-dry sludge, but, as the six kilns already erected were not sufficient to deal with the quantity of sludge now being produced at the works, it was in contemplation to build some additional kilns. By simply drying the sludge on a water-bath, there was a loss of about 50 per cent. of

Mr. Jacob.

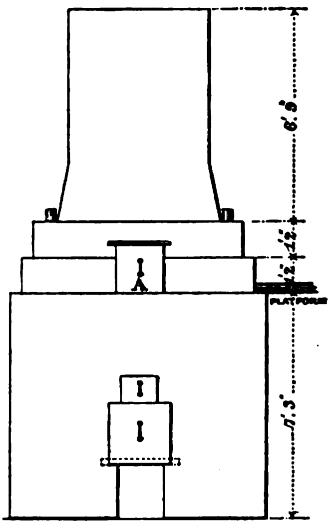
Mr. Jacob. weight; but the burning process got rid of 35 per cent. more weight in the shape of water and organic matter, leaving 15 per cent. of ash. This ash had no manurial value, and those who had taken small quantities on trial had never asked for more, although no charge had been made for the material. It was thought that the ash would consist largely of lime, which, being freshly reburnt, might with advantage be added to the sewage; but an analysis showed that there was only 1 per cent. of soluble matter in it, and

FIG. 1.



VERTICAL SECTION.

FIG. 2.



FRONT ELEVATION.

Scale $\frac{1}{72}$.

practically no phosphoric acid. The labourers at the works had, however, found a use for the ash. They employed it for dusting their barrows before filling them with the sludge, and without this or some other material such as sawdust, or dry sand, it would be difficult to detach the sludge from the barrows. At present there was no accumulation whatever of ash at the works. It would be observed that the kilns were exceedingly simple, even crude in form; but they answered their purpose well, and no nuisance was caused by them. They caused some smell in their immediate neighbourhood, such as was produced by the burning of rags, paper, or other organic substance, but none of an offensive or injurious character. In a closely inhabited district, it would no

doubt be advisable to arrange the kilns in groups, connecting them by a horizontal flue to a tall shaft, and the products of the combustion might even be conveyed through a furnace to burn them completely before passing them into the air. It might be argued that the sewage from a large manufacturing borough like Salford was not similar in character to the sewage of London or other water-closeted towns; and there was little doubt that the large amount of suspended matter in the Salford sewage, which was detached from velveteens and other fabrics, during the process of bleaching and dyeing, mainly accounted for the readiness with which the sludge burnt. He was nevertheless of opinion that, with carefully constructed furnaces and a strong draught, almost any sludge could be effectually destroyed, if a small quantity of the cheapest coal, or turf, or even cinders or ashpit refuse, were used. He had little confidence in mechanical pressure being ever found reasonably economical in dealing with the enormous bulk of sludge produced in the Metropolis and the larger provincial towns. Mr. Jacob.

Mr. H. Law desired to emphasize that which had been said as to the importance of presenting the chemicals employed in the clarification of sewage in a perfect state of solution, and further, of having sufficient subsequent agitation to ensure a thorough admixture, and afterwards a sufficient period of quiescence to allow of the precipitation of the solids held in suspension. Although the importance of subjecting the effluent after the removal of the matters held in suspension to aeration was generally acknowledged, the best results had not hitherto been realized, in consequence of the imperfect mode of application. This had been by merely agitating the effluent in contact with the air, by causing it to flow through long channels over a rough bed, or by allowing it to fall in cascades; whereas, in order to obtain the best result, the air should be presented to the effluent in a state of the finest division, and in such manner as to permeate the whole body. This could only be done by the injection into the effluent of a small jet of the effluent itself, which would carry with it a very large body of air in a state of the most minute division. A noteworthy experiment had been made by the late Mr. W. A. Lloyd, the Superintendent of the Crystal Palace Aquarium, at the International Exhibition of 1862, when 400 gallons of sea-water in a highly putrescent and offensive condition, quite black and in a poisonous state, were rendered clear and transparent and fit for the reception of animals, merely by the injection of the impure liquid itself in the form of a jet $\frac{1}{10}$ inch in diameter, and delivering only Mr. Law.

Mr. Law. 1 gallon per minute. The same system had been applied for many years past at the Crystal Palace Aquarium, where large quantities of shrimps, crabs, mussels, and oysters were thrown into the tanks to feed the fish and other marine animals, without producing any deterioration in the water. The air permeated the whole body of water in such a finely divided state as to appear like dust suspended in it.

Dr. Munro. Dr. J. M. H. MUNRO observed that he would confine his remarks to the question of the manurial value of the pressed sludge. Water-carried sewage was still an institution in most towns, and had to be got rid of with as little nuisance to the public, and as little cost to the ratepayers as possible. The experience of the last few years led to the conclusion (which had to a great extent been endorsed by the report of the last Royal Commission on Metropolitan Sewage Discharge) that whether the sewage was to be discharged into a river, or whether it was to be used for irrigation, or purified by intermittent filtration, the previous removal of the sludge by precipitation was highly desirable, and in some cases essential. Further, that the quickest and least obnoxious mode of dealing with the separated sludge was to treat it in filter-presses, and so reduce it to the half-dried condition now familiar under the name of pressed sludge-cakes. All these operations were undertaken without any idea of commercial profit, and solely to remove a nuisance in the best and least costly manner. But they happened to result in the recovery of perhaps one-fifth of the manurial value of the sewage in a very much more concentrated form than in the raw sewage itself; and the question then arose whether these pressed cakes were to be thrown away at a further charge on the rates, or whether they were to be disposed of so as to fulfil their only legitimate function, namely, that of manure. Even if they had to be given away to the farmers for nothing, this was by far the best mode of disposing of them, for all cost of getting rid of them was saved, and the manurial value was at any rate utilized; but when they were sold to farmers or dealers, as ought generally to be the case, every ton sold helped to reduce the cost of pressing, and every shilling obtained above 2*s*. 6*d*. per ton helped to reduce the cost of precipitation also. These considerations were obvious enough, but they were usually met with one of two replies:—(1) the manurial value of pressed sludge was either extremely small, or altogether imaginary; or (2) the manurial value might be all that was said, but it was not possible to get farmers to admit it, and as a matter of fact they would not cart the stuff away even when it was offered them for nothing. Those who denied the manurial

value of sewage-sludge did not base their opinion on its composition, or on any carefully conducted experiments. Sometimes they confounded pressed sludge-cakes with the old wet sludge; and from the disappointments of a few years back in trying to dispose of the latter substance, a sloppy liquid containing over 90 per cent. of water, not portable, and in chronic putrefaction, they inferred similar disappointment with the former substance, firm, compact, portable cakes, with only 55 per cent. water, and nearly free from smell. Or else they argued, as Mr. Dibdin appeared to do, that because farmers were not readily convinced of the value of pressed sludge, and because commercial men were not forthcoming to take the sludge off the hands of the municipal authorities, with a view to making a profit out of it, therefore the stuff itself really had no commercial manurial value. But farmers, like the rest of the world, were more easily convinced by advertisements than by reasons or experiments; and in the few cases in which commercial men had tried to make a market for sewage-sludge by advertising it, it seemed to him they had been far more successful than any one could have anticipated, in selling it at a price very much in excess of its real value as determined by its composition and by experiment. He thought this was to be regretted, and that the disposal of pressed sludge at a fair price was rendered more difficult by the extravagant claims that were made for it in some quarters. The question had a purely scientific basis, and the manurial value of sludge was to be inferred strictly from its composition and to be verified by properly conducted experiments. He had made manurial experiments with eight samples of sewage-sludge obtained by precipitation with the ordinary chemicals, and with four samples precipitated by the use of a material which was itself of considerable manurial value, and which therefore enriched the sludge. Confining himself to the ordinary sludges, not enriched, he found that in their dry condition they contained on the average of all the samples, 2·20 per cent. of phosphoric acid, equivalent to 4·80 per cent. of phosphate of lime, and 1·405 per cent. of nitrogen, equivalent to 1·706 per cent. of ammonia. Mr. Dibdin gave as the average composition of the (dried) sludge obtained at Crossness, 1·57 per cent. of phosphoric acid, equivalent to 3·42 per cent. of phosphate of lime, and 2·081 per cent. of nitrogen, equivalent to 2·527 per cent. of ammonia. The phosphoric acid was present as precipitated phosphate of lime (in some cases precipitated phosphate of iron or alumina), which Dr. Munro valued at 2*s.* per unit; the nitrogen was in his opinion quite equal in value to Dr. Munro.

Dr. Munro. the nitrogen of bone-manures, and he valued this at 13*s.* per unit of ammonia. He meant that no farmer would have any reason to grumble at paying these prices, if he bought such manures at any great industrial centre for cash, free on rail, but exclusive of carriage; as a general rule farmers paid considerably higher figures. Applying this to his own analyses, the result was 31*s.* 9*d.*, and to Mr. Dibdin's figures, 36*s.* as the manurial value of the constituents of 1 ton of average dried sewage-sludge. He had stated elsewhere[1] that he hoped to prove, by actual experiment, that the dried and ground sludge really possessed a manurial value approaching these figures, when tried side by side with artificial manures of known cost. In 1885 and 1886 he carried out extensive series of experiments to prove this; but in 1885 the exceptional dryness of the season, and in 1886 the mismanagement of those in charge of the plots, greatly interfered with the results. This year he hoped to experiment under circumstances which would permit of his direct personal control. Yet even from the most unfavourable season of 1885 he could quote numbers which bore out his conclusion. First, he might observe that negative results were of no value in these trials. For instance, he had applied 3 tons per acre of "Native Guano" to a crop without any perceptible increase over the adjacent unmanured plot; he did not conclude from this that "Native Guano" had no portion of the value which its advertisers claimed for it; for on the same crop dressings of well-established manures, Peruvian guano selling at £10 per ton, and fish-manure selling at £7 or £8 per ton also produced little or no effect. The season was simply too dry to favour the action of any manures whatever. Let experimenters with sewage-sludge bear in mind that the following conditions must all be present to attain success:—The manure must be in a proper condition, and properly applied; the soil must be in a poor condition; the crop must be one requiring phosphates; and the season must be rainy enough to favour the action of manures. Take the mere mode of applying the manure alone:—In 1884 he published in the "Agricultural Gazette" an account of some experiments, showing that when a suitable potato manure was simply sown under the sets, and covered with an intervening layer of earth, 6 tons of tubers per acre were obtained; and when the same quantity of similar manure was sown on the surface, and incorporated with the soil by a fork, 13 tons 5½ cwt. per acre were obtained. Now he would quote one or two experi-

[1] The Journal of the Society of Chemical Industry, vol. iv. 1885, p. 18.

ments with dried sewage-sludge, which bore out his estimate of its manurial value :— Dr. Munro.

39 sets of potatoes unmanured produced on an average .	64 lb. tubers.	
39 „ „ each manured with 4 oz. dried and ground Coventry sludge, containing 13½ per cent. moisture, 1·06 per cent. nitrogen, and 1·25 per cent. phosphoric acid, produced on an average	76	„
39 sets with 8 oz. per set of similar sludge, produced .	86	„
39 „ 1 oz. „ fish guano, containing 8 per cent. nitrogen and 17 per cent. phosphate of lime, produced	72	„
39 sets with 2 oz. per set of similar fish guano, produced	102	„

If the fish guano was valued on the same system as he had employed for the sludge, the result was £8 6*s.* per ton, very nearly the price it was actually retailed at; yet 1 oz. of it did not produce so much increase of crop as 2 oz. of sludge which he had only contended to be worth about 30*s.* per ton. A comparison with Peruvian guano gave similar results. Again, in his experiments on a crop of rape (1885):—

The unmanured plots produced on an average	153	lbs.
4 cwt. per acre of fish guano produced an increase over this of	121	„
8 cwt. „ of ordinary superphosphate gave an increase of	175	„
1½ ton „ of dried and ground Leyton sludge (moisture 27 per cent., nitrogen 1·05 per cent., phosphoric acid 1·28 per cent.) gave an increase of	192	„
10 tons per acre of farmyard manure gave an increase of .	296	„

If the 8 cwt. of superphosphate was worth 24*s.* then the 1½ ton of partly dried sludge was worth 30*s.*, and this figure was not extravagant when compared with the result attained with the 10 tons of farmyard manure, which in the actual circumstances he should value at 50*s.* to 60*s.* or more. He therefore still maintained that sewage-sludge was worth nearly its full calculated value when partially dried, finely ground, and intimately mixed with the soil. The only reason that he was aware of for discounting this manurial value at all, was, in order to save carriage and cost of applying it to the land, a somewhat more concentrated manure was desirable. This end was easily attained by the addition, immediately before use, of a little sulphate of ammonia, which of itself was too concentrated to be easily applied without admixture. If a manurial value of 30*s.* per ton or so could really be made available in dried and ground sewage-sludge, how came it that the pressed cake with 50 to 55 per cent. of water had often to be given away, or money paid for its removal, and that when sold it fetched only 2*s.* per ton or so? In

Dr. Munro. the first place, its manurial efficacy was greatly interfered with by its physical condition. To use it properly it must either be dried and ground in a mill, or it must be air-dried until it would easily disintegrate under the roller and harrow. In his experiments with unground sludge in 1884 he showed, that whereas 5 tons of partially dried Leyton pressed sludge in clods produced an increase over the unmanured plots of 4 tons 6 cwt. per acre, 5 tons of farmyard manure produced an increase of only 4 tons per acre. Even in this condition, therefore, it exerted an immediate effect rather greater than that obtained from the same weight of farmyard manure; but it must not be forgotten that it left in the soil for future use a much larger quantity of phosphoric acid and nitrogen than an equal weight of farmyard manure. At Salisbury, where the quantity of sludge produced was small (18 tons of pressed cake per week), and the district purely agricultural, there was not so much difficulty as at other places in getting rid of the cake. Up to the present time Mr. Bothams had succeeded in disposing of all that had been produced at 4*s.* per ton, and it was becoming more and more appreciated. It was his opinion that the farmers who sent their carts to the works, and paid this price to cart it away, were benefiting themselves as well as the ratepayers of Salisbury; for in addition to the return on the immediate crop, they were laying up in the soil a stock of fertility that would be useful in future years. He was aware that the conditions were very different in the Metropolis, or in a large town not easily accessible to the farmers. Yet it was well known that a very large quantity of stable-manure was brought into the London docks daily, and that probably a much larger quantity was produced in the Metropolis itself. No proposals were heard of to cart this out to sea at the expense of the ratepayers. That which came into the docks was, he believed, sent down in barge loads to the fruit growers in Kent, who thought they got it cheaply enough at about 3*s.* per ton. Could not part of the pressed sludge at any rate be disposed of in this way? To deal with the large quantity produced in the Metropolis, however, some special agency seemed necessary to prepare it for market, and to make a market for it. Mr. Dibdin argued that because no one appeared to be ready to do this, therefore it could not be done. He hoped time would tell a different tale, when certain preliminary questions had been decided, and amongst them was the least cost at which the pressed cake could be dried for grinding.

Dr. Pole. Dr. W. POLE had noticed the frequent references that had been made to the Royal Commission on Metropolitan Sewage Discharge,

to which he had had the honour of acting as Secretary. The Reports of that Commission had now been for some time before the public, and had of course been subject to the careful examination and criticism of those who best understood the subject, and the result had been a general approval, which, in his opinion, offered a strong testimony to the pains which the Commissioners, during their two and a half years' work, had taken to investigate the facts, and to come to a fair and just decision upon them. Even the Metropolitan Board of Works, though of course it could not be expected to acquiesce in those views of the Commission which strongly differed from its contentions, had, he thought, paid the Commissioners a well-merited compliment in accepting their conclusions as authoritative expressions of independent and unbiassed opinion, and as worthy of respectful attention. To what extent the measures now proposed followed the views of the Commission was a question he would not enter into. The enquiry comprised the investigation of obscure and controverted facts; the discussion of difficult and complicated problems; and the consideration of measures of vast importance to the public welfare; and it must have been pleasing to the Commissioners to receive such general testimony that they had faithfully and successfully discharged their duties. So far as regarded Dr. Pole's own small part in the matter, all he could say was that he felt very proud of the assistance he had been allowed to render in the conduct of the enquiry, and in the manner of placing its results before the world. He trusted that the Report (like that of another Commission with which he had been similarly connected [1]) might be of use for reference at future times, when the matter that had immediately occasioned it had passed away. Dr. Pole would add a few words as to some of the features of the Commissioners' Reports. The main points had already been frequently mentioned; the Commissioners had found that the evil effects resulting from the sewage-discharge were real and serious, and such as to require remedying; and they described, at much length, the nature of the remedies which they considered applicable. But there were some minor points on which their Report threw valuable light. In the first place, there had been an impression that as the quantity of water passing the outfalls during the time of the sewage-discharge was some hundreds of times greater than the quantity of sewage it received, the sewage must be very largely diluted. The investigations of the Commissioners showed that this idea was a fallacy, Dr. Pole.

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[1] The Royal Commission on Water Supply, 1869.

Dr. Pole. inasmuch as the water of dilution was not pure water, but water already contaminated. There seemed reason to suspect that, in the driest weather, the proportion of sewer-liquid contained in the river in the neighbourhood of the outfalls might possibly approach one-sixth of the whole volume of the river. Then again there had been a notion that by certain arrangements at the outfalls, the sewage there discharged might be made at once to descend the river, and so get clear away. But this was also found to be a fallacy; for it was certainly shown that, partly by the tidal action and partly by a more obscure process of mixture, some of the discharge at the main outfalls was carried up the river, to a distance extending, under certain circumstances, over almost the whole tidal range. It was also pointed out that this distribution upwards was increased by the occasional discharges of sewage matter from the storm-overflows within the Metropolitan area. And further, that the whole body of sewage discharged oscillated, up and down, for a long period in the tidal estuary before finally getting out to sea. The Commission gave all due credit to the various purifying processes naturally going on, without which, indeed, the neighbourhood of the river would soon become uninhabitable; but still the above considerations must always have an important bearing on the sufficiency of any remedial measures applied at the main outfalls of the sewage.

Professor Wrightson. Professor John Wrightson considered the subject of the disposal of sewage-sludge of so great national importance, that he ventured to express an opinion upon the agricultural value of it based upon direct trials in the field, which had come under his own notice, and in the conduct of which he had co-operated. These experiments had been carried out by Dr. Munro, but he wished to add his testimony to the accuracy, the correct principle, and the success with which they had been conducted. The uncertainty of field trials was always an important factor, which ought not to be lost sight of, in estimating their significance. But their absolute necessity, as the only method of bringing the value of a fertilizer to a crucial test, could not be denied. To ensure success, it was necessary to select land not already in a state of plethora, but rather in a state of depletion. Secondly, the variations in quality, which were always numerous in all soils, must be reduced to an average standard by means of a number of unmanured plots, judiciously scattered over the entire area experimented upon. Lastly, all field-experiments should be tried in duplicate, or quadruplicate, by which means individual and average results might either support or correct and qualify each other. These conditions had

all been observed in these experiments, and the result was not only favourable upon an average, but each plot corroborated the answer given by other similar plots, thereby supplying cumulative evidence as to the absolute value of the sludges employed. These experiments were of national importance, and bore directly upon the question as to the disposal of sewage-sludge. They would for ever offer a strong protest against the suggestion to waste a portable and valuable fertilizer, which would, if applied to fields, tend in no small degree to render the farmer independent of foreign supplies of manurial substances. Professor Wrightson.

Mr. Dibdin, in reply to the correspondence, observed that he had purposely avoided reference to patent schemes; he saw nothing in the communications of either Mr. Astrop or Mr. Conder to call for remark, other than that when Mr. Conder tried his system in his presence, on average samples of London sewage, he failed to realize the glowing expectations which he had held out. Mr. Bailey Denton assumed that, because somebody proposed something different for another place, therefore his suggestions regarding the Metropolitan sewage were fallacious. He could only refer Mr. Bailey Denton to his Paper, and quotations already given from it in reply to Mr. Sillar. Mr. Bailey Denton, as the joint proposer with Lieut.-Colonel Jones of an old scheme revived, considered that the outfall tanks would have to be superseded by an extension of the sewers to a point lower down the river. This might some twenty or thirty years hence be desirable, but even if so, a sum of money would have been saved by the adoption of the present plan, which would be sufficient to pay the whole cost of such an extension when necessary. Mr. Bailey Denton asked if it was likely that a precipitation scheme founded upon the use of a minimum quantity of chemicals, and subsequent oxidation to a certain extent of the effluent, would rectify the present condition of things? It had been shown by Mr. Gordon, of Leicester, that such a system, carried out at Mr. Dibdin's suggestion, completely answered all that was required in a case of far more difficulty than that of the Metropolis. It was evident that eventually, with an increase of population, the annual cost of treating the sewage would be much greater. Increased flow of sewage meant increased cost of its treatment. There was no occasion to assume a variation in the method of treatment to demonstrate such a proposition. As to the threatened nuisance, to several watering-places on the Kentish coast, if the Metropolitan Board of Works carried out the recommendations of the Royal Commission, the inhabitants of Southend were of opinion that they also would be subjected to an abuse if Mr. Dibdin.

Mr. Dibdin. the Board carried out Mr. Bailey Denton's plan. Mr. Gordon's experience at Leicester was such a complete proof of the correctness of the views that he had expounded on the sewage question, that he trusted it would be carefully read by all interested. Mr. Gordon gave his experience of the black ash waste recommended by Major Flower, and stated that in his opinion it was of very little value; in this view Mr. Dibdin concurred from personal experience. He felt satisfaction at the remark, that, in consequence of the reduced price of manganate of soda in 1886, Mr. Gordon was enabled to effect for £1 14*s.* per 1,000,000 gallons, what he had been unable to do formerly with other chemicals for £2 7*s.* 6*d.* With regard to details of the estimate of the Metropolitan Board, he regretted that he was not in a position to afford information as to the contents of unpublished official documents. Mr. Jacob's happy experience at Salford was probably unique, but the results there could hardly be expected in the case of the Metropolis. When farmers, agents, or other persons took away all the sludge for nothing, it would be time to think of charging for it; until then it must be got rid of somehow. The question of waste did not seem to have been fully considered. The annual waste of manurial constituents from the soil, by the washing down of detritus during periods of heavy rain, was greater than any that would take place by carrying some 150 tons of organic matter of a washed-out character daily to the sea. After only a moderate rainfall, the quantity of organic matter carried over Teddington weir in twenty-four hours would sometimes be from 300 to 400 tons. What, then, must be the enormous quantity of "manurial matter" washed out of the ground in the watershed of the Thames during a single flood period? The outcry against the supposed waste by taking the sludge out to sea was raised by those who had not realized the fact, that this so-called waste was insignificant compared with the quantity of matter annually carried to sea by storm-waters. If it were not for this "waste," how would the fish obtain their food? Dr. Munro concluded that his contention was that the sludge could not be utilized, because no one came forward to take it. In this Dr. Munro was wrong. His position was very simple: a nuisance had to be got rid of at the cheapest rate. If in the process a valuable by-product resulted, then let it be utilized; if that by-product was not utilized, and became a nuisance, it must be got rid of by other means, until such time as some one came forward to take it. If Dr. Munro could bring about such a desirable end, no one would be more ready than Mr. Dibdin to assist him, and to give him all credit for the success attending his exertions.

Mr. W. SANTO CRIMP, in reply to the correspondence, said that the most important question was that addressed to him by Mr. F. Gower, M. Inst. C.E., with regard to the disposal of the effluent water from the presses. In this connection he would observe that the difficulties of precipitation were diminished rather than increased, because if to ordinary sewage was added 5 per cent. of its volume of press-liquor, the visible action resulting was precisely similar to that produced by the use of an equal quantity of a solution of lime. He first observed this action on commencing to work the filter-presses erected for the Croydon Rural Sanitary Authority in 1881.[1] If it was desired to add lime in solution to sewage, as suggested by Mr. Dibdin, a quantity of water equal to 1·01 per cent. of the volume of sewage would be required for each grain of lime per gallon, 5 per cent. therefore nearly corresponded with 5 grains of lime per gallon. The amount of press-liquor produced daily at Wimbledon was 33 tons; the normal sewage-flow was 3,350 tons; the ratio of press-water to sewage was thus less than 1 per cent., and the dilution was very great. The difficulties of treatment not being increased, but rather lessened, the only additional cost was that of pumping, which at Wimbledon was inappreciable. He had felt, however, that it would be more satisfactory if he obtained from a chemist some reliable data with regard to the soluble constituents of this press-water; he had therefore sent a sample for analysis to Dr. Stevenson, who had kindly given him the annexed short report on the subject:— Mr. Crimp.

"This is practically a saturated solution of lime holding in

COMPOSITION of LIQUID from FILTER-PRESSES USED for SEWAGE-SLUDGE at WIMBLEDON. STEVENSON.

Components.	Grains per Gallon.	In parts per 100,000.
Total solid matter (dried at 120°)	260·40	372·00
Loss on ignition	28·20	40·40
Combined chlorine	4·69	6·70
Lime (CaO), total, as free lime, carbonate, and soluble salts	131·30	187·57
Alkalinity, calculated as hydrate of calcium (slaked lime)	151·70	216·71
Free ammonia	6·90	9·86
Albumenoid ammonia	1·80	2·57
Oxygen required to oxidize the organic matter in two minutes	2·00	2·86
Ditto in four hours	3·05	4·36

[1] Minutes of Proceedings Inst. C.E. vol. lxxvi. p. 322.

Mr. Crimp. solution a good deal of organic matter . . . . The only useful purpose that I can see is served by returning the press-liquor to the unpurified sewage, is a saving of lime; there being the equivalent of rather more than 1 cwt. of quicklime in 33 tons of press-liquor, your daily yield . . . . It may with care, as *e.g.*, neutralization with sulphuric acid, be converted into a comparatively rich fertilizing liquid; but the 33 tons would require 2 cwt. of oil of vitriol for neutralization, and this would cost much more than the value of the fertilizers in the liquid." Dr. Stevenson further said that, in his opinion, the best way of treating the press-water was to add to it ten to twelve times its volume of chalky water, and pass it over or through land. He pointed out that by adding this liquor to the sewage the albumenoid ammonia in the latter was increased by $\frac{1 \cdot 8}{100} = 0 \cdot 018$ grain per gallon. In a Paper read last year before the Society of Arts,[1] Dr. Tidy suggested separate treatment of this liquor by chloride of lime, or perchloride of iron, in larger quantities than those used in sewage treatment. In Mr. Crimp's opinion the treatment should depend on the manner in which the effluent from the settling tanks was to be disposed of. If the effluent was to pass direct into a river of moderate size, as at Aylesbury, for instance, separate treatment might be desirable; but where the effluent passed over land for further purification, as at Wimbledon, the method adopted there might with safety be applied, and any fertilizing properties in the liquid would be in this way appropriated by the land. He would further point out, that whether the sludge was pressed, or was allowed to flow on to drying-beds, the amount of liquid to be disposed of was the same, and that its condition, when flowing from a press, was immensely superior to that of the exceedingly foul liquor as it flowed from drying-beds, and for that reason he did not approve of the method adopted for its disposal by Mr. Jacob at Salford. It was impossible that there could be sufficient aeration of the soil forming the filter under the wet sludge, and the purification of the foul liquid must therefore be almost entirely confined to the mechanical effect of the soil. Mr. Crimp had experienced much difficulty in dealing with this liquid at Wimbledon before filter-presses were erected. Mr. Gordon had adverted to the fact that the quantity of wet sludge yielded per 1,000,000 gallons of sewage differed very much. This was due to a variety of causes, being influenced by the leakage of subsoil water into sewers, thus

[1] Journal of the Society of Arts, vol. xxxiv. p. 1127.

increasing the sewage flow per head, by manufactories, by the nature of the precipitants used, &c. In the subjoined Table the Mr. Crimp.

Town.	Population.	Process.	Sludge-cake per million Gallons.	Per Head per annum.	Cost of Pressing exclusive of Charge on Capital account.	Authority.	Remarks.
			Tons.	Cwt.	s. d.		
Brentford	12,000	Lime and alum	8·16	1·730	2 1½	Lacey .	Sold £10 per annum.
Chiswick	20,000	Ditto	7·788	2·184	5 0	Hetherington	Taken by farmers.
Coventry	45,000	..	8·5	2·77	2 5	Coddington	Sold at 1s. per ton.
Croydon Rural Sanitary Authority	22,000	..	3·5	1·650	3 0½	Chart	Last six months' produce sold, £25; sewage not chemically treated.
Leyton . .	43,000	Lime and black ash . . .	10·99	2·410	1 8	Dawson	Pay farmers to take it.
Wimbledon	24,500	Lime and alum	10·20	2·120	2 6	Crimp .	Part sold, part used on Board's land.

comparatively large amount of sludge-cake produced at Leyton, compared with the other towns, was probably due to the fact that, in addition to the 15 grains per gallon of lime, considerable quantities of black ash waste were also used. A gratifying feature of the Table was the low cost of pressing at Leyton. From his personal observation of these works, he was enabled to confirm the cost given by Mr. Dawson. The explanation was chiefly due to the fact that, whereas twice as much sludge was pressed at Leyton as at Wimbledon, two men only were necessary for the work, and the item for labour only amounted to 4¾*d.* per ton as against 10¾*d.* per ton at Wimbledon; the sludge-cake, however, was not pressed to quite the same degree of dryness as at Wimbledon; and partly for this reason the yield per head was slightly greater, whilst the cost of production was lessened; at this low rate the cost of reducing the wet sludge to cake was only 4*d.* per ton of the wet material. The high cost of production at Chiswick was due to the unsatisfactory mode adopted for the introduction of the sludge into the presses. The series of experi-

Mr. Crimp. ments by Dr. Munro proved, beyond all question of doubt, that when pressed-sludge was properly prepared, it was a manure of even greater value than Mr. Crimp's moderate estimate, whilst the manner in which the experiments were conducted, as stated by Professor Wrightson, showed that the utmost care had been taken to ensure accurate results.

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1 February, 1887.

EDWARD WOODS, President,
in the Chair.

The following Associate Members have been transferred to the class of

Members.

Edward Buckham.
William Allan Carter.
John George Hudson.
John List.
Percival Walter St. George.
Arthur Moore Thompson.

The following Candidates have been admitted as

Students.

Arthur Stowey Bailey.
Alfred Jackson Batt.
Francis George Coles.
Herbert Evington.
Clarence Noël Goodall.
John Joseph Hedges.
Henry Wilson Hodge.
Follett Holt.
William George Crawford Hughes.
William Marshall Huskisson.
Herbert Sidney Jurd.
Norman Larchin.
Percy Edward Lewis.
Edward Bickerton Milward.
Arthur William Pritchard.
Lazarus Simon Magnus Pyke, F.C.S.
Harry Richardson.
Richard Stanfield, Wh. Sc.
William Elphinstone Underwood.
William Henry Wickham.
George James Wooldridge.

The following Candidates were balloted for and duly elected as

Members.

Alexander Joseph Bolton.
William Buchan Christie.
Charles Edward Livesay.

Associate Members.

Robert Ogilvie Newton Anderson, B.A., B.E., Stud. Inst. C.E.
Jonathan Angus.
James Rae Baterden.
Frederick Bluett, Stud. Inst. C.E.
Robert Henry Burnside Downes, Stud. Inst. C.E.
Henry Somerville Fearon, Stud. Inst. C.E.
Maurice Fitzmaurice, B.A., B.E., Stud. Inst. C.E.
Arthur Edmund Breton Hill, B.A.Sc.
Robert West Holmes.
John Bagot Labatt, Stud. Inst. C.E.
Alexander Gordon McBeath.
Frederic York Marrian, Stud. Inst. C.E.
Donald Alexander Matheson.
Thomas William Potter, Stud. Inst. C.E.
Samuel Reesch.
James Robert Robertson.
James Robinson.
John Burn Anstis du Sautoy.
Edward John Silcock, Stud. Inst. C.E.
Cyril Smith.
Henry Badeley Smith.
Charles Alexander Stevenson, B.Sc.
James Pickles Wilkinson.
William Winstanley.
Fred Spencer Yates, Stud. Inst. C.E.

The discussion, upon the Papers by Mr. W. J. Dibdin and Mr. W. S. Crimp, occupied the evening.

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8 and 15 February, 1887.

EDWARD WOODS, President,
in the Chair.

The discussion, upon the Papers by Mr. W. J. Dibdin and Mr. W. S. Crimp, occupied both these evenings.

22 February, 1887.

EDWARD WOODS, President,
in the Chair.

(*Paper No. 2219.*)

"Irrigation in Lower Egypt."[1]

By William Willcocks, Assoc. M. Inst. C.E.

Owing to the absence of rain, the agriculture of Lower Egypt depends entirely on irrigation. In Upper Egypt, where the basin system of irrigation prevails, the country along the banks of the Nile is divided by extensive dykes into a series of basins, varying in size from 50,000 to 8,000 acres each. These basins are filled with water from the Nile in August and September and emptied in October. Shakespeare gives an exact account of the system of agriculture:—

> "They take the flow o' the Nile
> By certain scales i' the pyramid; they know,
> By the height, the lowness, or the mean, if dearth
> Or foizon, follow: The higher Nilus swells
> The more it promises: as it ebbs, the seedsman
> Upon the slime and ooze scatters his grain,
> And shortly comes to harvest."

The crop of wheat, flax or beans, is sown without ploughing in November, and reaped in March. During the summer, from April to July, countless temporary wells are dug, which supply water by means of shadoofs, to excellent crops of millets, cucumbers and melons. This is the system of irrigation Nature meant for Egypt; yearly the rich slime is renewed, and the soil still retains the fertility for which it has been famous since the earliest times. In Lower Egypt all this is changed. Here the year is divided into three seasons, corresponding with the phases of the Nile and the changes of the climate. The first season is the "séfi," or summer, which extends from the 1st of April to the end of July, while the Nile is at its lowest. At this time the discharge of the Nile varies from 12,000 cubic feet per second, in a bad year, to 25,000 cubic

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[1] See "The River Nile." By B. Baker. Minutes of Proceedings Inst. C.E. vol. lx. p. 367; and "Notes of a Journey through the N.E. portion of the Delta of the Nile in April 1884." By W. Anderson. Minutes of Proceedings Inst. C.E. vol. lxxvi. p. 346.

feet per second during an exceptionally good one, the average discharge being 14,000 cubic feet per second. The summer crops are cotton, rice, sugar-cane, melons and cucumbers, while clover is irrigated up to the beginning of June. The summer is followed by the "Nili," or flood season, which lasts through August, September, October and November, when maize is grown. The flood crop of maize is the staple of food for the whole agricultural population. During the floods, besides the maize, cotton, rice and sugar-cane are irrigated and matured, and the fallow land, of which there is very little, is put under water. At this time the maximum Nile discharges vary from 187,000 cubic feet per second during a year of low Nile, to 387,000 cubic feet per second during a year of very high Nile. The third season is the "Chitawi," or winter, during the months of December, January, February and March. The winter crops are wheat, beans, barley and clover. A discharge of from 25,000 cubic feet per second to 55,000 cubic feet per second can be depended on during the winter.

Taking the Deltaic provinces of Menufieh and Garbieh, with which the Author is directly concerned, the importance of the different seasons may be thus compared:—

Total area paying taxes = 1,170,000 acres.

Summer Crops.

	Acres.		£.
Cotton	390,000,	yielding	3,600,000
Sugar-cane	3,000	„	36,000
Vegetables	3,000	„	30,000
Rice	35,000	„	245,000
Total	431,000	„	3,911,000

Flood Crops.

	Acres.		£.
Maize	560,000,	yielding	2,240,000
Flood rice	30,000	„	60,000
Total	590,000	„	2,300,000

Winter Crops.

	Acres.		£.
Tobacco	3,000,	yielding	21,000
Flax	2,000	„	20,000
Vegetables	7,000	„	70,000
Wheat	320,000	„	1,600,000
Barley	170,000	„	340,000
Beans	120,000	„	600,000
Clover	380,000	„	1,140,000
Total . . .	1,002,000	„	3,791,000

Practically the whole area yields a double crop, which may be valued at £10,002,000. It is not pretended that the above figures are exact; they embody the result of three years' study and observation. To accomplish this irrigation there are employed 11,708 water-wheels, 1,123 portable engines with a joint HP. of 9,895; and 162 stationary engines with a joint HP. of 2,395. The summer crop is the most difficult and expensive to raise; while the great task of the irrigation engineers in Lower Egypt is to supply and distribute the water fairly. To obviate difficulties imposed on summer irrigation by the low level of the Nile, Mehemet Aly began the Barrages at the head of the Delta in 1835, under the able direction of Mougel Bey; and had it not been for the corvée, or forced labour, he would have finished them. The presence of the corvée enabled the Government at first to dig the canals deep and dispense with the Barrages; and when afterwards difficulties arose owing to inferior workmanship, which inferior work Mougel Bey was compelled to execute in a hurry, it seemed easier to the Government to keep on calling out the corvée than to face the problem of the Barrages and definitely solve it. To these deep canals Egyptian irrigation owes all its difficulties. Canals meant to irrigate small tracts of land, and needing during flood a bed width of 10 feet and a depth of 6 feet, have bed widths of 10 feet and depths of 20 feet. They run 3 feet deep in summer, and suffice for the summer crop, which covers about one-third of the whole area commanded. During flood they irrigate the whole area, but have to run 20 feet deep in order to ensure flush irrigation along their entire lengths. The result is that regulators have to be built at intervals of 8 or 10 miles along the canals, and closed during flood to bring the water to the surface of the land. This converts the canals into a series of pools, which form very efficient silt traps. The checking of the velocity causes the Nile mud to settle in the beds of the canals in deposits of 8 feet and under on hundreds of miles. This has to be removed yearly by the corvée at enormous cost. Hundreds of acres of valuable land lie buried under thick deposits of mud, while the fields themselves lose this rich mould. But this is only the beginning of evils. In spite of the closed regulators, and numerous other contrivances, the canals are so disproportionately large during flood, that they send down into the lower lands further north such an excessive volume of water, that all the canals, escapes, and drainage cuts are full to overflowing with flood-water, and are in consequence unable to perform their proper functions. The country during flood is divided into a number of islands surrounded by water at a

high level. The natural consequence is that salt efflorescence is greatly on the increase in the lands under cultivation; while 300,000 acres of land in Garbieh, capable of being reclaimed by drainage and basin treatment, are maintained in a state of swamp. Owing besides to the existence of so many regulators, about 2 per cent. of which are provided with locks for navigation, the canals are no longer the magnificent highways for the conveyance of produce which they once were. Indeed, many poor lands are not cultivated at all, because the cost of transport is prohibitive.

The deep summer canals are supplemented in floods by a network of shallow canals, which run only during high Nile. The Nile begins to rise about the 1st of July, but in this month the rise is not generally sufficient for flood irrigation, which begins usually about the 10th of August. Early in August the rise attains an average daily rate of 1 foot, until the maximum of 20 feet above summer level is reached. At this stage of the Nile it is from 3 to 8 feet above the level of the country, which is protected from inundation by dykes. As soon as the water is high enough to flow into the flood canals, the sowing of maize begins, and is continued to the middle of September. The maize is sown very close together and is gradually thinned as it grows, providing food for the cattle during this season of the year. The early-sown maize yields twice as much corn as the late. For flood irrigation, therefore, an early rise of the Nile is the best. The Nile at Assouan reaches its maximum about the 20th of September, and would, under ordinary circumstances, be at its highest in Lower Egypt about the 25th of September; but as the basins of Upper Egypt are being filled in August and September, the Nile in Lower Egypt is only moderately high. Between the 1st and 10th of October, the basins are opened, and the Nile in Lower Egypt is at its highest about the 15th of October. A high Nile at Assouan, about the beginning of October, omens ill for Lower Egypt, as the addition of water from the basins means excessive floods. By building proper regulating works among the basins, and opening them with precision, it will be possible to supplement a low flood, and prevent a high one from being dangerous. The end of the floods is contemporaneous with the reaping of the maize crop, which is followed by a final heavy irrigation of the whole country, and the subsequent sowing of the wheat crop after ploughing, and the clover without ploughing.

It will now be easy to comprehend that the problems before the irrigation engineer in Lower Egypt are the following:—

1. The strengthening and securing of the Barrages, so as to ensure a constant high-water level during summer.

2. The construction of escapes and supplementary flood canals, so as to irrigate during summer from the summer canals, and during high Nile from flood canals, and thus prevent slime deposits.

3. The obtaining of a flood-supply as early as possible in the canals.

4. The drainage of the lowlands, and their restoration by means of basin irrigation to their original fertility.

5. The conversion of the salt plains near the inland lakes into cultivable land.

6. The protection of the Nile dykes during flood.

7. The opening of routes for navigation, so as to convey the produce of the fields cheaply to the markets.

8. The regulation of the water-supply.

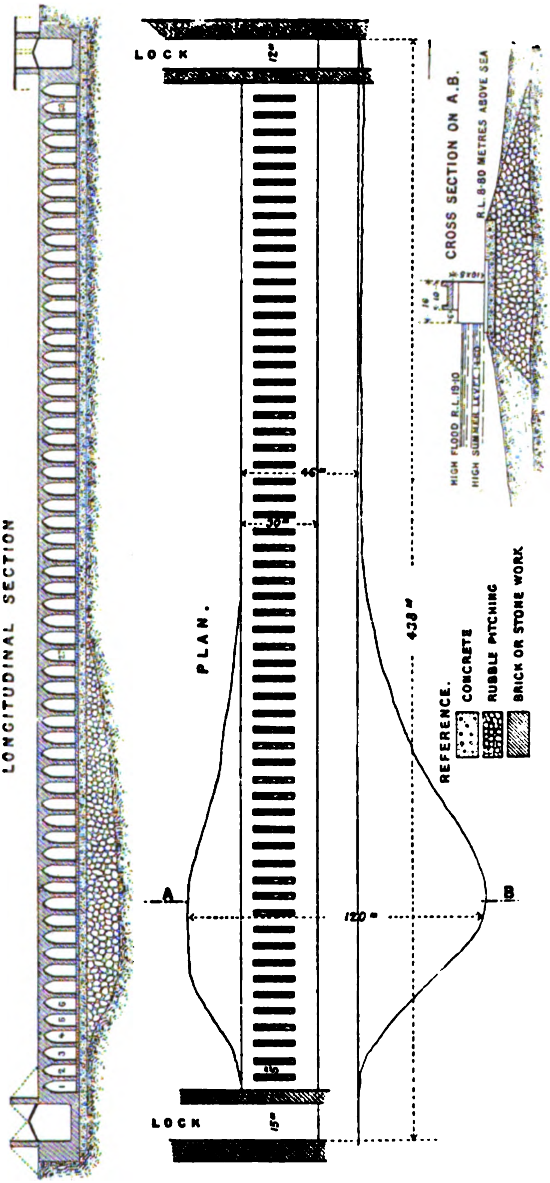
The Author will confine his remarks to the provinces of Menufieh and of Garbieh, which, with the Barrages, formed the circle under his charge during 1884 and 1885:—

1. The Barrages.

In January, 1884, the Author would have thus described the two Barrages. The Nile Barrages are open dams thrown across the heads of the Rosetta and Damietta branches, at the apex of the Delta. Of the two branches the Rosetta has nearly twice the flood-supply of the other, while its bed is some 6 feet lower; on it are placed two pumping stations for supplying the Béhéra province with water during summer. The Damietta branch feeds eight important canals. The Rosetta Barrage is 1,437 feet between the flanks, and the Damietta 1,709 feet. These Barrages are separated by a revetment wall 3,280 feet in length, in the middle of which is situated the head of the Delta Canal. The platform of the Rosetta Barrage is flush with the river bed, being 29·8 feet above mean sea-level. Its width is 151 feet and depth 11·5 feet. It is composed of concrete overlaid by brick and stone work. Downstream of the platform is an irregular talus of rubble pitching, varying in places from 150 feet to 10 feet in width, and from 50 to 2 feet in depth. The left half of the platform is laid on loose sand, the right half on a barrier of rubble pitching overlying the sand. This loose stone barrier is 30 feet high, 200 feet wide at the deepest part, and tapers off to zero at the ends. It closes the original deep channel of the river, and its only cementing material is the slime deposit of the Nile. This deposit is so excellent that the barrier

is practically watertight. The platform supports a regulating

Fig. 1.



Rosetta Branch Barrage, January 1884.

Scale $\frac{1}{3,000}$.

It is proposed to make the remodelled high summer level 14·60 metres, at present it is 13·60 metres, above mean sea.

bridge with a lock at each end. The bridge consists of sixty-

one openings, each 16·4 feet wide; the lock on the left flank is 39·4 feet wide, while that on the right is 49·2 feet. Fifty-seven of the piers are 6·6 feet wide, while three of them are 11·6 feet wide; their height is 30·2 feet. The lock walls are 9·8 and 14·8 feet wide. The piers support arches carrying a roadway and a system of fortifications. The two locks are provided with drawbridges and fortifications. Taking 62·6 feet as the high flood-level, the waterway of the Barrage is 34,359 square feet, while the high-flood discharge is 225,000 cubic feet per second, causing a banking up of 0·8 foot. The concrete of the platform is considered inferior, while Mougel Bey, the builder, condemns that under the ten openings from No. 48 to No. 57, owing to the hurry in which he was compelled to complete it. The floor here settled 0·4 foot during the floods of 1867, producing a deflection in the superstructure both horizontally and vertically. These ten openings are enclosed within a cofferdam 16·4 feet high and 6·6 feet broad, composed of a wooden framework packed with stone, resting on the platform. Of the sixty-one openings, forty-seven are regulated by means of iron gates, and the remaining fourteen by vertical wooden piles resting against oak horizontals. The iron gates are each 16·4 feet broad and 19·7 feet high; shaped like the arc of a circle, and supported at either end by iron rods radiating from the arc to the centre; here they are attached to massive iron collars working round cast-iron pivots embedded in the masonry of the piers at the centres of the arcs. The curvature of the arcs is down-stream, and the pivots are consequently up-stream, of the gates. Powerful crabs, travelling on rails at the roadway level, raise and lower the gates by means of chains attached to the bottoms of the gates. The iron gates and wooden piles when lowered do not reach the platform of the Barrage; they rest on iron gratings 1 foot high, fixed into the piers just above the platform. These gratings allow of a free passage of the water when the gates are down. They were originally put in to prevent deposits of slime in front of the gates. It is reported that men have been sucked through the foundations of the Barrage; it would be more correct to say that they have been drawn through these openings.

The Damietta Barrage has ten openings more than the Rosetta Barrage, of 16·4 feet each. The platforms and superstructures are on the same level and exactly similar. No records exist of the state of the foundations, but Mougel Bey states that the work here is excellent, since it was practically built in the dry. This Barrage is partially supplied with wooden horizontals, but has never

been used for regulation. The 49-foot lock is unprovided with gates.

Previous to 1884 the Barrages were regulated in the following manner:—When the Nile gauge stood at 43 feet,[1] which generally happened in March, the Rosetta Barrage gates and piles were quickly lowered to their full extent, beginning at opening No. 1, and closing at opening No. 61. The consequence was a rapid current through the last openings just before they were closed. It was on one of these occasions that the ten openings from No. 48 to No. 57 were injured, according to the report of the Egyptian foremen on the work. The Government report states that they were injured during the floods of 1867, owing to contracted waterway. As soon as the gates and piles reached the gratings they could descend no further, and the work of regulation was at an end for that year. The up-stream gauge rose to 44·6 feet, while the down-stream gauge fell to 38·9 feet; so that, with a difference in water surface of 5·7 feet, there was a gain in water-level of only 1·6 foot. This was due to the fact that the Damietta Barrage was open. Of the water which escaped through the Rosetta Barrage, practically the whole found its way through the iron gratings. These gratings, with a head of 5·7 feet, were capable of discharging over 8,000 cubic feet per second. The river kept falling through April, May, and June, and during the whole of this time the Damietta Barrage was open, as well as the gratings of the Rosetta Barrage. There was not sufficient water in the Nile to allow of a head of 5·7 feet on the latter, and it fell to 3·3 feet. Towards the end of June the up- and the down-stream gauges roughly indicated 41·3 feet and 38·1 feet respectively. If the Rosetta Barrage had failed in June, the loss of head in the Delta canals would have been 1 foot. When the Nile began to rise in July, and the up-stream gauge read 44·6 feet, the gates were raised as quickly as possible, the river fell to 43 feet, and was allowed to recover as the flood rose. This it did generally in six or eight days.

After an inspection of the Barrages in January 1884, and a comparison of previous gauges, it was determined to maintain above the Barrages a constant gauge of 44·6 feet. This resolve was supported by the following considerations:—

The studies of Mr. (now Sir John) Fowler, Past-President Inst. C.E., had proved that the brickwork on the surface of the platform was good, however inferior the concrete substructure might be.

The severe action below the Barrage when a gate was lowered to

[1] All levels are reduced to "mean sea."

its full extent, was found to be due to iron gratings, or "windows" in the foundation, and not as it had been supposed to a honeycombed foundation. This fact was apparently unknown to the writers of the reports on the Barrages. Indeed it ought to have been evident that if all that action was due to fissures in the foundations, the Barrage would have been swept away years ago.

The Okhla dam at Delhi on the River Jumna, a mass of loose rubble stone with absolutely no foundation, holds up yearly 10 feet of water, when the water-pressure per lineal foot bears to the weight of the dam a proportion of $\frac{3.125}{129.600}$ or $\frac{1}{40}$. Nile sand is much finer than that in the Jumna, and will therefore require a lower coefficient; but this is a difference of degree and not of kind.

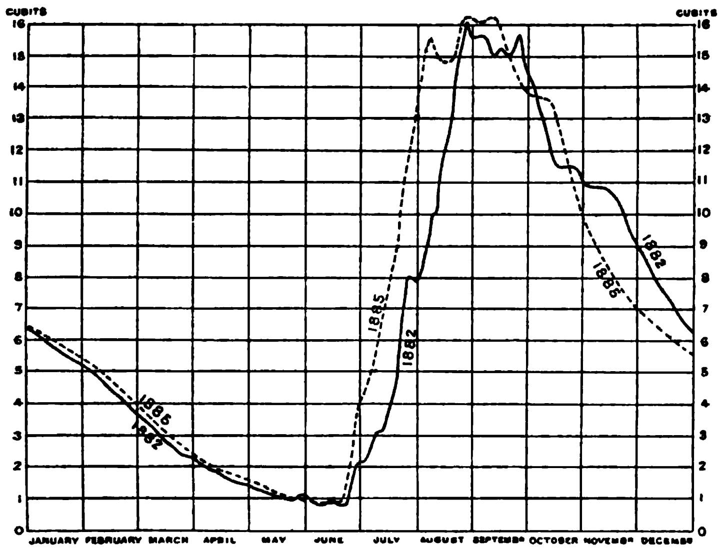
Considering the Barrage a thoroughly unsound work, and relying only on friction, it was determined to make the submerged weight of masonry bear a ratio of 50 to the pressure of the water going to be brought on it. Springs might cause a slight subsidence of any part of the Barrage, but it could not be moved as a whole. The pressure of a head of 10 feet of water would be 3,125 lbs. per lineal foot. The submerged weight of the platform was 103,983 lbs. per lineal foot. The coefficient between them was $\frac{1}{33}$. That this proportion might be $\frac{1}{50}$, it was necessary to make the rubble talus everywhere 131 feet wide, and 10 feet deep, with a submerged weight per lineal foot of 51,668 lbs. This made the submerged platform and talus together 155,651 lbs. as compared to the pressure of 3,125 lbs. Since only $\frac{1}{3}$ of the talus was completed in 1884, the Barrage was not required to hold up more than 7·2 feet of water; on the completion of the talus in 1885, 10 feet of water were held up.

About the end of January 1884, the river gauge fell to 44·6 feet. From this date the gates and piles were gradually lowered in the Rosetta Barrage, so as to maintain this gauge. When the gates reached the gratings, and the piles were driven home, the work of closing the gratings was taken in hand; while the talus was strengthened with 671,015 cubic feet of rubble pitching. Owing to the incomplete state of the talus no more than 7·2 feet of water were held up on the Barrage. Attention was now directed to the Damietta Barrage, which was strengthened with 494,432 cubic feet of rubble pitching; the left flank lock was closed with a stone dam, the right lock was repaired and opened for navigation and a channel for boats dredged to and from it; and all the openings were provided with oak horizontals and sheet-piles, and gradually closed. At this juncture Nubar Pasha, at Colonel Moncrieff's request,

gave a special grant of £18,000 over and above the ordinary budget, and so enabled the work to proceed without interruption. Eventually at the end of the season, the Rosetta Barrage held up 7·2 feet, and the Damietta 3·3 feet, while the water-surface above the Barrages was 44·6 feet instead of 41·3, as it would have been under the ordinary method of working. On the 7th of July the Nile began to rise; on the 13th of July the Damietta Barrage was opened, and the Rosetta between the 18th and 31st.

The Nile at Assouan during the summer of 1885 was lower than it had been in 1884, and almost similar to what it was in 1882.

FIG. 2.



ASSOUAN GAUGE (Southern Boundary of Upper Egypt).

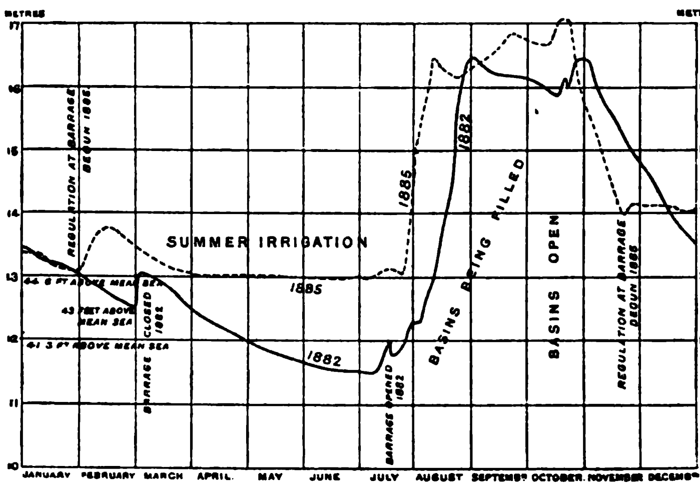
Scale 1 cubit = 54·04 centimetres = 1·773 foot.

The Author has therefore plotted the Nile curves at Assouan (Fig. 2) for 1882 and 1885, and also at the Barrage (Fig. 3), for comparison. It will be seen that the water-surface above the Barrages in 1885 was 4·1 feet higher than what it was in 1882. During 1882 a discharge of 1,720 cubic feet per second entered the Delta Canal; during 1885 there was a uniform discharge of 4,200 cubic feet per second. This year the talus was completed with 1,271,399 cubic feet of rubble pitching, and a small temporary stone dam was raised on it, with its crest at reduced level 38·05 feet, so that the Barrage might hold up 6·7 feet, and the

stone dam 3·3 feet, or 10 feet of water between them, the pressure being distributed. This dam was removed before the flood, and the materials were added to the talus. The wooden horizontals were found untrustworthy in both Barrages, and rolled-iron beams were substituted. The cofferdam round the ten weak openings was considerably strengthened. Eventually the Rosetta Barrage held up 10 feet, and the Damietta Barrage 5·6 feet, of water. The Nile began to rise on the 5th of July, and the Barrages were completely opened by the 24th.

During 1886 Mr. Perry, who had been Resident Engineer in 1884 and 1885, was put in charge of the Barrages, and worked on

FIG. 3.



BARRAGE GAUGE. UP-STREAM.

Zero of Barrage Gauge 60 centimetres above mean sea.

the same lines as in 1885, with the same results. The work of repairing the Barrages out of the £1,000,000 loan was begun this year under Mr. A. Reid, of the Public Works Department of India, and the floors of five openings were exposed, examined, and made watertight. This work will be prosecuted with great vigour in 1887, at the end of which year it will be possible to give a detailed account of the system of protection adopted.

Besides regulation, the training of the Nile on to the Barrages has been steadily pursued, the Government granting £3,800 per annum for the work. The works have been in progress three years, and it is expected that in another two years the original

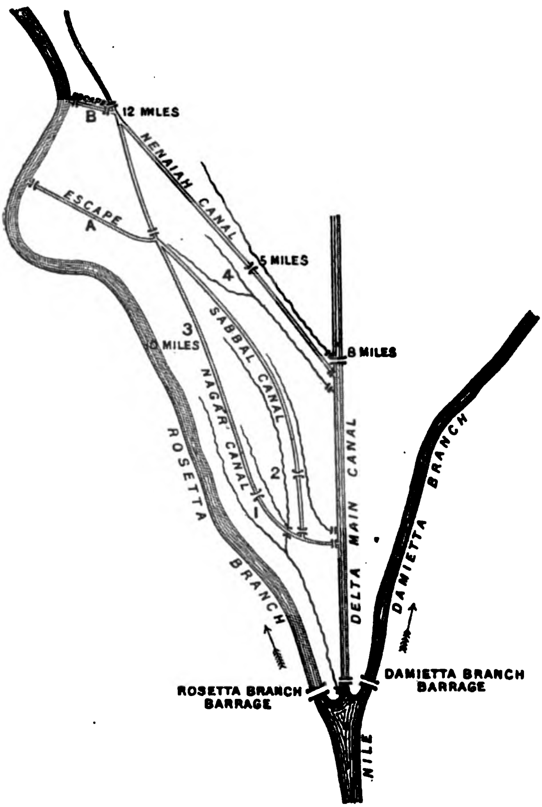
scheme will be completed. This consists in bringing the Nile flood on to the apex of the Delta, and there distributing the supply. The apex has been fixed at a point about 2½ miles up-stream of the Barrages. Individually the Author would have preferred making the head of the Delta Canal (at the middle of the revetment wall) the apex, but in this he was overruled. However, the steady pursuit of the present plan will overcome all difficulties and gain the desired end, if only it is adhered to. In January 1884 the whole Nile was flowing along its left bank to the Rosetta Barrage, at about ½ mile above which the waters were divided, two-thirds of the supply passing down the Rosetta branch, while the remaining one-third ran along the revetment wall between the two Barrages, and so reached the Damietta branch. The latter was practically a spill-channel for the Rosetta branch. Sir Charles A. Hartley, K.C.M.G., stated, in 1877, that if something were not done in the direction of river-training, the Damietta branch of the Nile would silt up, just as five out of the seven ancient mouths of the Nile had done during the course of the last eighteen centuries.

2. Slime-Deposits.

With respect to the reduction of slime-deposits in the canals, the raising of the water-surface above the Barrages has already done much in this direction, but much remains to be done. The expenditure on some of the canal clearances was extravagantly high compared with the results obtained from the clearances. The greatest offenders in the Delta were the Sahel and Nagár canals. The annual cost of the former was £15,000 for corvée labour, and gave a summer discharge of 80 cubic feet per second; the cost of the latter was £18,000, and gave a discharge of 40 cubic feet per second. Pumping-engines, delivering water at a 12-foot higher level, would have delivered 600 cubic feet of water per second into each canal for the same money. As the corvée expenditure, however, did not appear in the Budget, public attention was not directed to it, as it would otherwise have been. The accompanying plans (Figs. 4 and 5) show the work done on the two above-mentioned canals. The Nagár Canal, with the Sabbal and Nenaiah, formed one system of summer canals. Out of these canals the corvée cleared, in 1884, 31,906,388 cubic feet of slime, at a cost of £45,172. After the remodelling works were put in hand, the clearances were reduced to 3,727,913 cubic feet in 1886, costing £6,334, while it is anticipated that in 1887 the clearances will fall to 1,059,500 cubic feet, costing £1,800.

The remodelling works have cost altogether £15,000, and, with the higher level of water at the Barrage, have practically done away with the slime-clearances altogether. Referring to Fig. 4, the double lines show the original summer canals, and the single lines give the new flood canals, which now accomplish the whole of the flood irrigation. During high Nile the summer canals are partially

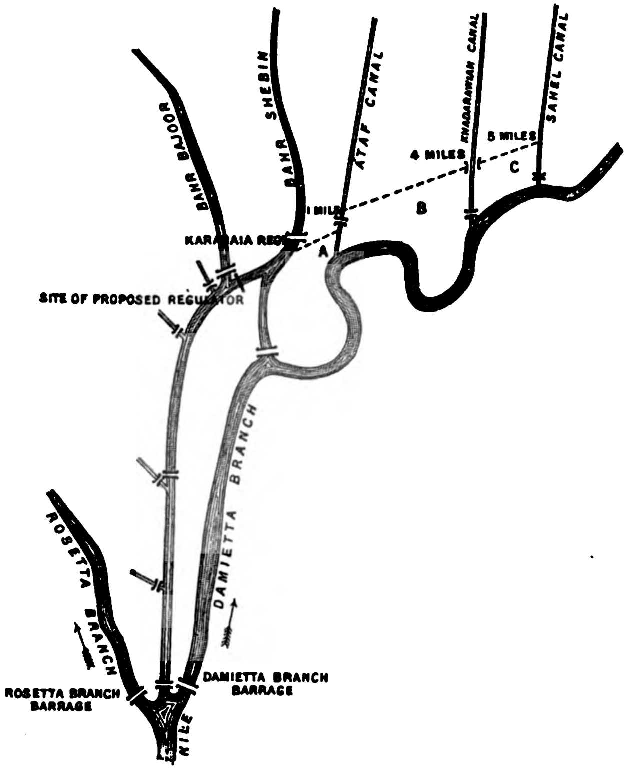
FIG. 4.



closed at their heads, and the supply of water sent down suffices for the flush irrigation of the low lands in the lower reaches. The regulators, numbered 1, 2, 3, 4, are unused, and all surplus water is discharged down the two new escapes marked A and B, which tail into the Nile. The water now is always in motion, and the slime cannot be deposited in the canals. A party of engineers is employed in taking fortnightly discharges of all the canals, com-

paring the discharges obtained from surface-velocities with the discharges obtained from surface-slopes, and measuring the depths of slime or sand deposited in each fortnight. The observations are still in progress, but it has been already established that a velocity of over 2 feet per second in August and September, when the Nile water is much charged with slime, prevents deposits, not only of slime, but even of sand. In October far lower velocities suffice,

Fig. 5.



since the Nile water is diluted with the clear basin-water of Upper Egypt. Fig. 5 gives the Sahel, Khadarawiah, and Átaf system, which originally were fed from the Nile during both summer and flood. By excavating, at a cost of £9,000, the new summer canal A B C, which is fed by the main Delta Canal during summer from above the Karanaia regulator, at any level that may be considered convenient, the slime-clearances are dispensed with. During flood the canals take their water direct from the Nile. The prin-

ciple on which all the changes are made is that summer irrigation, both as to its channels and sources of supply, must be kept quite distinct from flood irrigation.

3. Early Flood Supply.

Next in importance to a plentiful supply of water in summer is the securing of an early supply in July and August, in order to ensure a good maize crop. The equatorial rains of Central Africa and Abyssinia reach Egypt late, owing to the great length of the Nile, while winter in Lower Egypt sets in early; time, therefore, is of great importance. To secure an early flood supply, a new regulator is necessary at the head of the Bahr Shebín. At its 14th mile the main Delta Canal divides into two branches; of these the left branch is known as the Bahr Bajoor, and the right as the Bahr Shebín. During August the Nile Barrages are open, and the water in the Nile and the main canal is at the same level. By building a regulator at the head of the Bahr Shebín, and closing it in August, the whole supply coming down the main canal will be turned down the Bahr Bajoor, while the Bahr Shebín will take its supply direct from the Nile. By utilizing existing works and channels, and spending £16,000, it will be possible to nearly double the water-supply of the two central provinces during the rise of the Nile, and so secure an early maize crop everywhere. For besides the extra value of an early maize crop itself, it is very desirable that the final flood-watering, which prepares the land for the winter crop-sowing, should be given when the Nile water is high enough for flush irrigation. Since the Nile falls very quickly after the 20th of October, the sooner the maize crop is off the ground the less is the chance of there being any necessity to lift water by machinery for the winter crop.

4. Basin-Irrigation for the Low Lands near the Sea.

The two preceding paragraphs have reference to the country for a distance of 65 miles north of the Barrages. The next belt, of 15 miles in width, was in former days, judging from the ruins of towns and villages, as fertile as the first; it is now very different. When cotton-cultivation was introduced, about forty years ago, all the fields in this tract were planted with cotton, and produced fairly well; gradually the lower fields fell out of cultivation, owing to salt efflorescence and lack of drainage. As the higher fields were now required to produce a double share of an exhaustive crop, while they received no manure or slime-deposit,

they had to be planted with cotton and rice alternately, to prevent their complete deterioration. The drainage water of the rice fields was run on to the lower lands, and completed their ruin. New canals, dug without levels or alignment, and the conversion of all the drainage cuts into irrigation canals, was all that was needed to destroy the higher lands. This soon followed. In many places now, the tops of the old banks and the beds of the old canals are the only places which yield a crop at all. Still, with a persistency worthy of a better cause, the cultivation of cotton is insisted on, and here and there a wretched peasant may be seen ploughing up the bed of a contracted drain or canal in the middle of a vast salt plain. The only remedy for this is a return to the basin system. It seems ridiculous that during the summer months, when the water has no fertilizing property, and there is very little of it, landowners should go to the greatest expense to lift it on to a dozen fields from among a thousand. These few fields they have to toil at through the year, and when the flood comes, with rich fertilizing water in plenty, and at a suitable level for irrigation, thousands of watchmen are turned out to guard the dykes which keep it within its banks, and prevent it from reaching the land it covered in old days. If the country were divided into basins, and the flood-water allowed to inundate them, there would be deposited a rich soil, which, without ploughing and without irrigation, would yield a magnificent crop, a hundredfold more valuable than the sickly rice or cotton now produced. It must be possible to restore to this land the fertility it once enjoyed under the Pharaohs, who were acquainted with no arts which moderns do not possess, but under whom what is now a desert was then a garden, and what are now numberless ruins were populated towns and villages. Since nothing better than the Pharaonic system of basin-irrigation is known, it has been attempted to re-introduce it on a large scale; while all the old drainage cuts are being thoroughly deepened and cleared, and prevented from being used any longer as canals. Considerable ameliorations must result from the intelligent pursuit of a system which answered so admirably in Upper Egypt for thousands of years.

5. Basin-Irrigation for the Lands bordering the Lakes.

The belt of land north of this last tract is, if possible, still worse. Here a fresh evil has cropped up. Through neglect of ancient dykes and ancient systems of regulation, the sea has been allowed to mingle with the Nile water, and the two combined

have been driven by the prevailing N.W. winds over the flat low-lying land. This tract is composed of barren salt plains, from which rise numberless mounds strewn with bricks and pottery. The canals here have no dykes, and though the Nile water itself, unmixed with salt, pours over some of the plains, no crop is produced except on the edges of the canals, where all the slime is deposited owing to the want of basins. The whole country appears to be inundated by the red muddy water of the Nile, but stepping out of a boat and walking away direct from the canal, it will be found that the water is red for a few hundred feet, after that it is colourless, and then black and stagnant, blasting the land it covers. The lands inundated by the red water produce a crop, the rest yield a coarse grass or are barren. If the summer supply in the Nile were sufficient for the irrigation of all the land, it might easily be converted into one extensive rice-field; but as this supply is available in one year only out of fifty, it is useless to consider proposals of reclamation by superior rice-culture, and recourse must be had to the basins which are filled during the flood. It may be noted in passing that the Nile flood arrives too late to mature a good rice crop; there is a coarse quality of rice produced by the flood, but the yield is so insignificant that the lands so cultivated pay no revenue.[1] The area of land capable of being reclaimed in Garbieh alone is over 600,000 acres, and as 10*s*. per acre is the tax paid by inferior land in Egypt, the project seems worth a trial. A sum of £10,000 has already been spent in so reducing the flow of the canals into Lake Borillos, that its summer area of 160,000 acres will not be increased to 490,000 acres in flood-time as heretofore. Last year over 18,000 cubic feet per second entered the lake; this year barely 5,000 cubic feet per second. Dykes and drains are under construction, while the opening between the lake and the sea is being watched to see the effect of the decreased supply.

6. Nile Protection.

Previous to 1884 it was customary to protect the reaches of the Nile, where the scour was severe, with rubble pitching spread

[1] The summer or superior rice known as "Sultáni" gives twice as large a yield as the flood or "Sabáini" rice, while its price is one and three-quarter times as high. The latter, however, might be much improved by careful culture. If the lands were ploughed in summer and exposed for three months to the sun, sown with Sabáini rice at the beginning of the flood, and carefully weeded during flood, the yield and quality would both be improved, while the lands themselves would be partially reclaimed.

over the slopes. This practice has been discontinued, as it was only a temporary expedient and had no permanent effect. The stone has now been collected at suitable sites, and the nucleus of spurs begun. Yearly the money allotted for Nile protection is spent in adding to these spurs. In a dozen years they ought to completely protect the banks, as the sum allotted is a handsome one. Besides the above purely protective works, training works are in progress in many places. Owing to the enormous quantities of sand and clay brought down by the Nile flood, at a velocity which can just keep the liquid moving, the slightest impediment produces heavy deposits, and renders the work of river-training easy and effective.

7. Navigation.

The most important navigation works in hand are the ten new locks under construction; their cost is to be defrayed from the £1,000,000 loan, under the direction of Major Western, R.E., Assoc. Inst. C.E. Besides making the principal canals in the Delta navigable along their entire lengths, they will keep open the through traffic between Cairo, Alexandria, and Damietta during the summer, when the Nile branches are not navigable. In addition to the above main lines of communication, some of the subsidiary canals are being taken up; but the work of combining navigation, drainage and irrigation, with their conflicting interests, is so difficult and costly, that the Author is inclined to the idea that light tramways would pay better, provided any company could be found to construct them, without demanding concessions of through lines competing with the Government railways.

8. Regulation of Water-Supply.

In order to ensure a fair distribution of water during summer, the approximate areas of summer cultivation on each canal have been tabulated; gauges erected at the heads of the minor canals, and the regulators of the main canals, and discharges measured fortnightly, and proportioned to the areas cultivated. The regulating heads of all the minor canals have been repaired sufficiently to allow of speedy opening and closing, while the main canal regulators have been thoroughly renewed. To complete the system, a new regulator and lock have been built in the main canal at a cost of £21,000. The gauges to be maintained up-stream of the main canal regulators, and down-stream of the minor canal

heads, have been determined. The utilizing of the main canal regulators during summer has resulted in a great reduction of silt-clearances in the minor canals. Formerly the Government refused to allow a single regulator on the main canals to be touched during summer. The Government wanted to regulate from Cairo, and thought that the safest way to prevent unscrupulous men in the district from closing off too much water was to keep the regulators open. By this means the authorities certainly gained this end; but the silt-clearances rendered necessary on all the minor canals, in order that summer-water might be taken in at a low level, were a heavy burden on the corvée. By using the regulators, the silt-clearances have been reduced to one-fifth of what they were, while the water distribution has been improved. For now the minor canals have their water-level from 1 foot to 2 feet below that in the main canals, and it is therefore easy to increase or to reduce supply whenever necessary. Summer irrigation is far more indispensable for the low lands at the tails of the canals, than it is for the rich lands at their heads. Of the 1,170,000 acres in the second circle, about 850,000 acres are capable of producing, between the 1st of August and the 31st of May, two excellent crops, one crop of maize during the floods, and the other of wheat, beans, or clover during the winter. To the inhabitants of such lands cotton is a luxury; they can pay their taxes without cotton. The remaining 300,000 acres are incapable of producing maize owing to dampness; but they can produce good cotton and rice, and to such lands therefore as much water as possible should be sent down during the summer. Up to the present, it has been difficult to do anything in this direction, since the landholders at the heads of the canals have been encouraged to think that they have a right to put up pumping-engines wherever they feel so inclined. All increased supplies of water resulting from future improvements should be sent on to the lands incapable of producing maize.

The level of water in the Damietta branch of the Nile, at the heads of the two great systems of canals fed by that branch, has been raised during summer by dams of loose stone. Each dam contains about 500,000 cubic feet of stone, and has cost £5,000. The dams hold up 3 feet of water during summer. Their crests are lowered towards the end of July, and the floods pour over them without any signs of afflux. The crests are renewed yearly in April at a trifling cost. The Rosetta branch of the Nile near the town of Rosetta is closed yearly, at a cost of £8,000, with an earthen dyke which holds up 2½ feet of water, and during summer keeps out the sea, which, on the Egyptian coast, never rises more

than 2·5 feet under the actions of tides and storms combined. The dyke is swept away at the beginning of each flood. All the above works must be continued till the Barrages are repaired.

The regulation of water for summer irrigation is thrown into great confusion, about the 15th of July, by the cultivators on the summer canals taking water for their maize before the flood has really come. Flood-irrigation, properly speaking, begins when the water is high enough to flow into the flood canals, which ordinarily takes place about the first week of August. Not satisfied with waiting for the flood, the larger cultivators on the summer canals, from about the 15th of July, work their engines and water-wheels night and day, while the smaller ones turn out with kerosene tins worked as shadoofs, and a dozen other contrivances, to irrigate their lands and put in maize. Since the area under irrigation is trebled, while the supply of water at the heads of the canals is unaltered, there results, as a natural consequence, a very serious deficiency of supply at the tails of the canals. Near the tails of the canals are situated all the rice-fields, a crop which cannot stand a ten days' closure without injury. Tales of the incapacity of the Irrigation Department form, therefore, the ordinary topics of conversation in Lower Egypt from the 15th of July to the 7th of August. For it must be remembered that though the Nile is rising, the water-level above the Barrages is constant, while all the extra supply coming down the Nile helps to swell the two branches below the Barrages. When both the branches are filled, and the Barrages completely opened, the real rise begins. Not ten Egyptians outside the Public Works Department realize this. At present, owing to the absence of any canal law, the only action which the irrigation officers can take is to close with earthen banks for ten or fifteen days all the canals which irrigate only cotton; but as many of the cotton-irrigating canals have rice at their tails, matters are complicated. The cotton crop in July can easily stand a fifteen or twenty days' closure. Indeed it seems to be improved by it, as the drought kills the cotton worm or addles the eggs. At this season, the Author thinks it would be better to allow the water at the up-stream gauge at the Barrage to rise from 44·6 feet to 47·9 feet, taking care that the amount of water held up was not more than 10 feet. During flood the regulation is easy; but as the cultivators have been accustomed to a steady supply at this season, they object to the periodical openings of the regulators. The regulators are opened in order to generate a current and to remove the slime deposits. Time will conquer this objection. During winter all the masonry

works are repaired, and the canals cleared, for the coming summer. The irrigation work is easy.

The staff of Egyptian engineers employed on the work has invariably given the most efficient and ready help. To their cheerful co-operation is due whatever success has attended the measures adopted in the direction of proper regulation.

The Author concludes this Paper by remarking that in Upper Egypt, where the old Pharaonic system of basin-irrigation exists, every acre of land is cultivated and pays revenue, while the soil is as rich to-day as it was thousands of years ago. In Lower Egypt, on the contrary, where the improved system of irrigation prevails, and a triple crop is gathered, one-third of the area is uncultivated, while the remaining two-thirds are incapable of paying a higher revenue than Upper Egypt. The improved system, besides, has only lasted some fifty years, and yet there is a cry of the deterioration of the soil and produce from one end of the country to the other—a cry which is re-echoed by English cotton-spinners. Nature wants the slime of the Nile flood to be deposited on the land; it is now forced into the sea; and though it is not necessary to go to the full extent of Napoleon's statement, that were he master of Egypt he would never allow an ounce of slime to be wasted, yet it may be stated, without fear of contradiction, that for every £1 of profit resulting from the expenditure of £1,000 on the improvement of the existing irrigation system, £10 would be the return on money spent in a partial restoration of the basin-system where the lands are cultivated, and a complete restoration where the lands are not under cultivation.

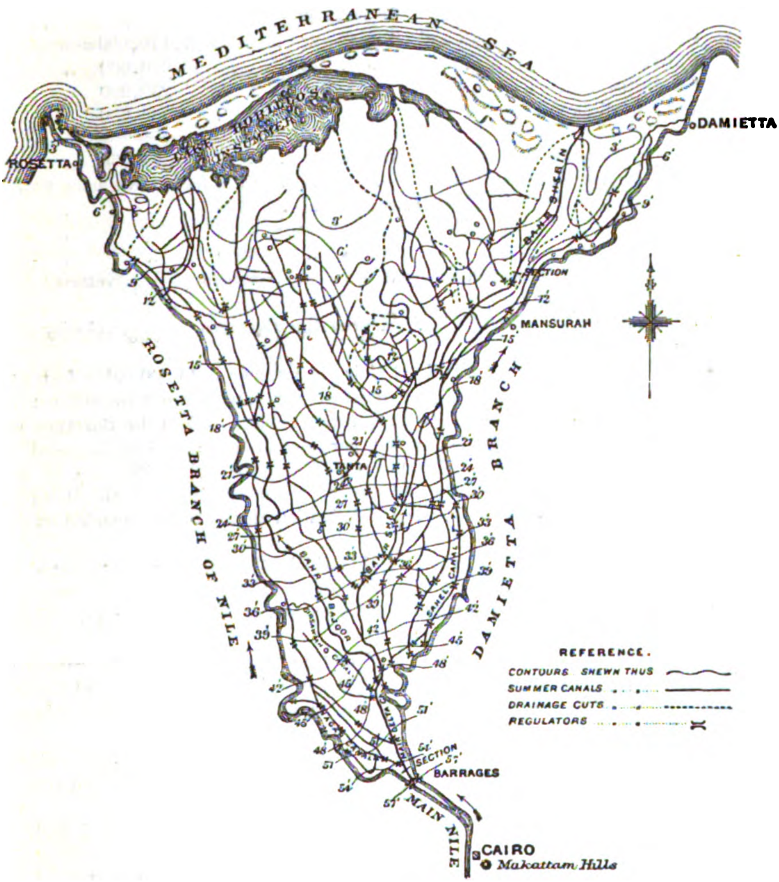
This Paper is accompanied by several diagrams, from which the Figs. in the text have been engraved.

[APPENDIXES.

APPENDIXES.

APPENDIX I.—Hydrographic Map of the Provinces of Menufieh and Garbieh, Lower Egypt, 1887.

Fig. 6.



Scale $\frac{1}{1,600,000}$.

Contours 3 feet apart above mean sea.

APPENDIX I.—Hydrographic Map of the Provinces of Menufieh and Garbieh, Lower Egypt, 1887 (Fig. 6).

Total length of summer canals	1,431 English miles.	
,, ,, flood canals	747 ,, ,,	
,, ,, drainage cuts	174 ,, ,,	
Maximum flood Rosetta Branch	225,000 cubic feet per second,	1878.
,, ,, Damietta ,,	162,000 ,, ,,	,,
Minimum ,, Rosetta ,,	116,000 ,, ,,	1877
,, ,, Damietta ,,	71,000 ,, ,,	,,
Cultivated land, Menufieh and Garbieh	1,170,000 acres.	
Cultivable ,,	670,000 ,,	
Sandhills	250,000 ,,	
Lake Borilles in summer	160,000 ,,	
	,,	
Total area of the two provinces	2,250,000 ,,	
High-flood level at the Barrages	62·6 feet above mean sea.	
Ordinary summer level above Barrages	44·6 ,, ,,	
,, ,, ,, below Rosetta Barrage	34·6 ,, ,,	
,, ,, ,, ,, Damietta ,,	39·0 ,, ,,	

Slope of Rosetta Branch in flood near the Barrages $\frac{1}{11,000}$, velocity 4 to 5 feet per second.

Slope of Damietta Branch in flood near the Barrages $\frac{1}{13,000}$, velocity 3 to 4 feet per second.

The ordinary discharge available at Cairo in summer is 14,000 cubic feet per second. Of this discharge 10,500 cubic feet per second are now utilized in irrigating 1,155,000 acres in the Delta during summer. When the Barrages are completed the whole 14,000 cubic feet per second of water will be used in irrigating during summer 1,540,000 acres. Since the cultivable area of the Delta exceeds 5,500,000 acres, the reclamation of Lower Egypt or the Delta by summer irrigation is impossible. Flood irrigation alone can be depended on for reclamation.

Of the 1,170,000 acres in Menufieh and Garbieh, 431,000 acres are irrigated in summer. During flood the summer crop and 590,000 acres of flood crop are under irrigation. In winter 1,002,000 acres are sown with winter crops. There is practically a double crop every year.

In summer about 4,250 cubic feet of water per second enter the canals of Menufieh and Garbieh; during flood 17,500 cubic feet per second; and during winter 6,000 cubic feet. During flood and in winter all the canals discharge into the sea or lake at the tails.

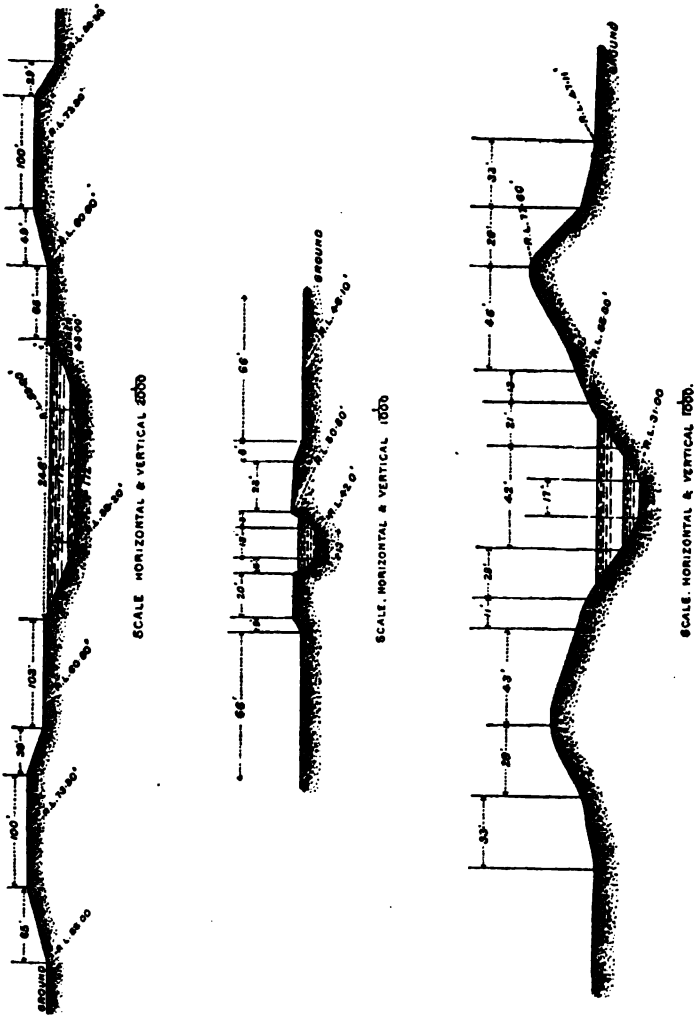
During flood and in summer there is no rainfall. In winter there is a slight fall of rain in the northern half of the Delta, and a little at Cairo; but practically none in the southern half of the Delta.

During summer and flood it is assumed that the evaporation is ¼ inch in twenty-four hours.

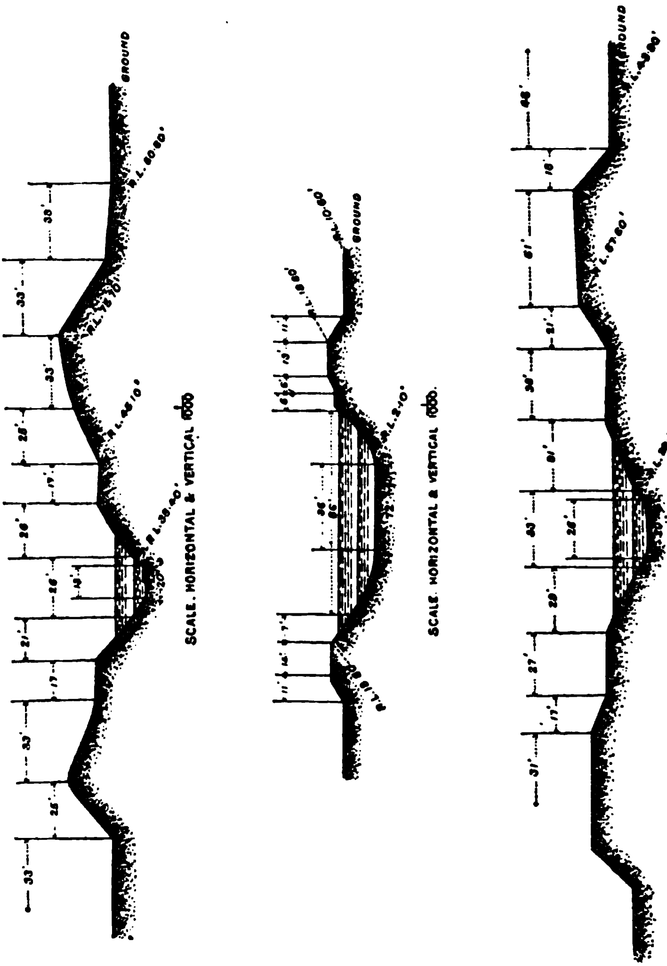
The level of the springs rises and falls with the Nile. In summer it is about 12 feet below the surface at the head of the Delta, and gradually reaches the surface at Lake Borillos. At that time of the year each branch of the Nile is fed by infiltration water at the rate of about 600 cubic feet per second.

Near the Barrage the slope of water surface in the Rosetta Nile is greater in summer than in flood; in the Damietta Nile, on the contrary, it is greater in flood than in summer.

APPENDIX II.—Details of some Canals in the Delta (Figs. 7).



APPENDIX II. (Figs. 7)—*continued.*



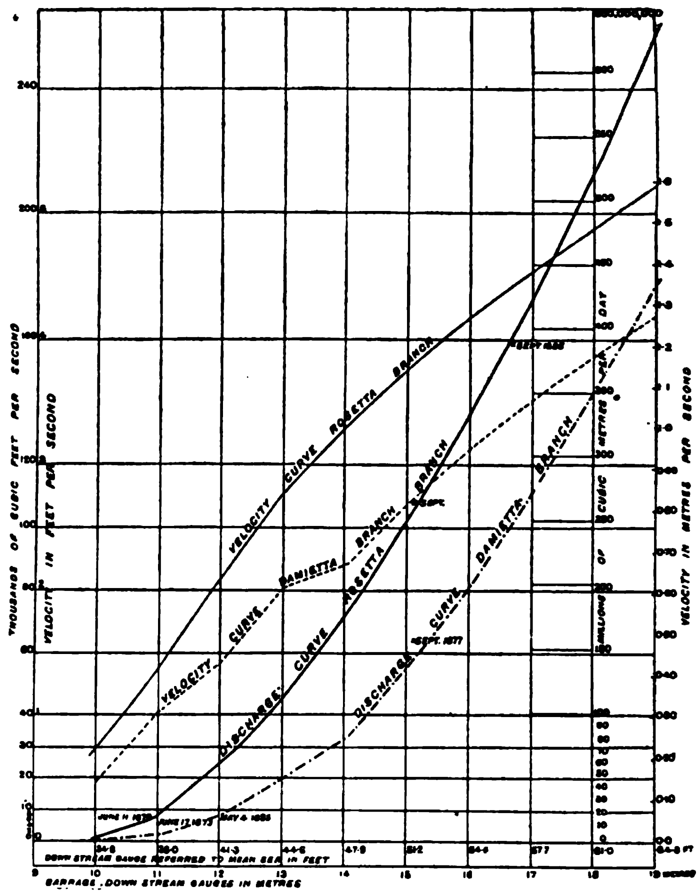
APPENDIX II.—Details of some Canals in the Delta of Egypt (Figs. 7).

Canal.	Season.	River level.	Bed width.	Depth of Water.	Area.	Slope.	Velocity per second.	Discharge per second.	Observations.
		Feet.	Feet.	Feet.	Square feet.		Feet.	Cubic feet.	
Main Delta canal at head	Flood .	53·0	174	20	3,652	$\frac{1}{15,000}$	2·97	10,846	The Delta main canal receives 3,943 cubic feet per second from this head, and 250 cubic feet per second from another feeder during the summer, irrigation performed by minor canals.
	Summer	43·0		10	1,643	$\frac{1}{12,000}$	2·40	3,943	
Main Delta canal on Bahr Shebín at tail	Flood .	16·0	72	14	1,010	$\frac{1}{15,000}$	2·25	2,272	Closed by an earthen bank at the tail during summer.
	Summer	8·0		6	287	$\frac{1}{100,000}$	0·37	106	
Sirsawiah canal at head	Flood .	48·1	20	17	650	$\frac{1}{20,633}$	1·75	1,138	During flood the second regulator is opened every alternate week and the velocity increased.
	" .			7	650	$\frac{1}{11,944}$	2·20	1,430	
	Summer	34·5		3·5	100	$\frac{1}{12,000}$	1·10	110	
Nagár canal at head	Flood .	48·4	20	10	453	$\frac{1}{14,000}$	2·00	906	Remodelled supply; same alternate regulation as above. Irrigation performed by minor canals.
	" .			10	453	$\frac{1}{26,900}$	1·40	635	
	Summer	43·9		3·5	100	$\frac{1}{12,000}$	1·10	110	
Sahel canal at head	Flood .	41·4	20	12	613	$\frac{1}{25,641}$	1·60	981	Remodelled supply.
	Summer	32·9		3·5	100	$\frac{1}{12,000}$	1·10	110	
Subk flood canal .	Flood .	48·2	13	6	114	$\frac{1}{20,000}$	1·00	114	

When the velocity is less than 1·8 foot per second in flood, silt is deposited. During summer there is no silt deposit as the water is clear.

APPENDIX III. (Fig. 8).—DISCHARGES AND MEAN VELOCITIES OF THE ROSETTA AND DAMIETTA BRANCHES OF THE NILE BELOW THE BARRAGE.

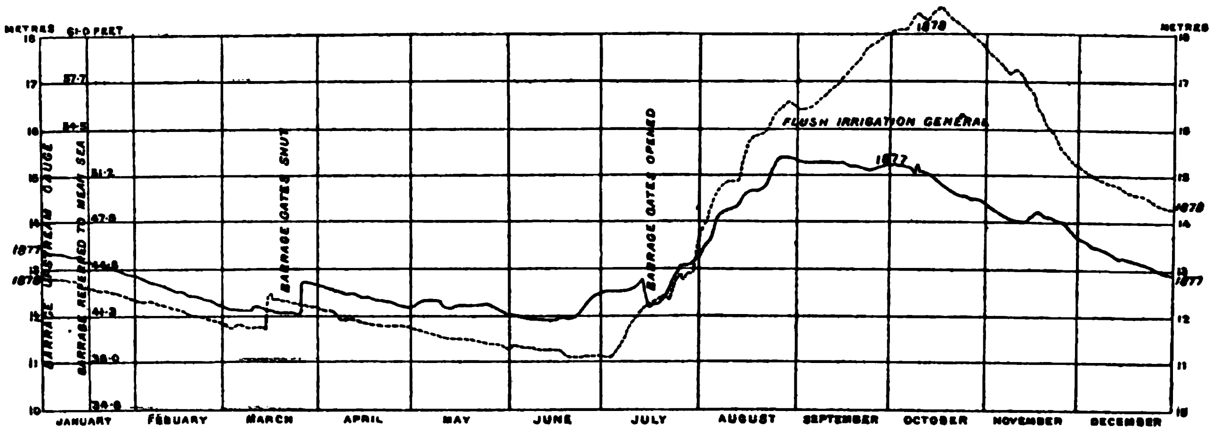
FIG. 8.



Calculated from slope and cross-section, and verified by surface velocity observations, by Major Webster and Mr. A. Reid, using Bazin's coefficients.
Maximum flood this century at Barrage.
Downstream gauge: Rosetta, 18·25; Damietta, 18·50.
Minimum flood this century at Barrage.
Downstream gauge: Rosetta, 15·25; Damietta, 15·40.

APPENDIX IV.—Maximum and Minimum Nile this Century during Flood (Fig. 9).

Fig. 9.



Upstream Barrage-Gauge Curves.

1877. Nile too low for Upper Egypt basins. Famine caused Ismail Pasha's deposition.
1878. Nile banks breached. Inundations in Lower Egypt.

APPENDIX V.—Earthwork executed in Menufieh and Garbieh (Second Circle of Irrigation) from 1883 to 1886.

—	1883. Corvée.	1883. Paid Labour.	1883. Total.	1884. Corvée.	1884. Paid Labour.	1884. Total.
No. of corvée on earthwork . . .	5,148,075	..	..	4,685,465	..	..
Money value of above corvée in . .	205,723	..	..	187,418	..	..
Cubic feet of out-turn	250,487,260	..	..	149,182,600	..	..
,, work by paid labour . .	..	..	..	..	27,357,000	..
Cost of paid labour, £	..	..	..	..	17,849	..
Total work by corvée and paid labour in cubic feet . . .	..	..	250,487,260	..	..	176,489,600
Total value of earthwork . . . . £	..	..	205,723	..	..	205,267
No. of corvée on Nile Protection . . .	3,065,420	..	..	455,300	..	..
Money value of above corvée . . . £	91,963	..	91,963	13,659	..	13,659
Total cost of earth work and Nile Protection . . £	..	..	297,686	..	..	218,926

—	1885. Corvée.	1885. Paid Labour.	1885. Total.	1886. Corvée.	1886. Paid Labour.	1886. Total.
No. of corvée on earthwork . . .	824,008	..	..	2,042,324	..	..
Money value of above corvée in £ . .	82,960	..	..	81,673	..	..
Cubic feet of out-turn	12,768,893	..	..	29,237,648	..	..
,, of work by paid labour . .	..	59,185,310	..	..	62,922,200	..
Cost of paid labour, £	..	46,869	..	..	39,223	..
Total work by corvée and paid labour in cubic feet . . .	..	..	71,954,203	..	..	92,159,848
Total value of earthwork . . . £	..	..	79,829	..	..	120,996
No. of corvee on Nile Protection . . .	1,755,295	..	..	1,754,150	..	..
Money value of above corvée . . . £	52,659	..	52,659	52,624	..	52,624
Total cost of earthwork and Nile Protection . . £	..	..	131,988	..	..	173,620

1884—First year of English supervision. Since 1884 the heavy canal work has been done by the corvée and the light by the contractors. Moving the corvée from small canal to small canal is very wasteful.

APPENDIX VI.—Details of Earthwork in Appendix V.

—	1883.		1884.	
	Cubic Feet.	£.	Cubic Feet.	£.
Summer canals . . .	130,279,000	145,723	84,452,400	140,564
Flood canals	120,158,260	60,000	64,680,200	46,859
Drainage cuts . . .	..	..	..	..
New projects . . .	..	..	27,357,000	17,849
Total . . .	250,437,260	205,723	176,489,600	205,267

—	1885.		1886.	
	Cubic Feet.	£.	Cubic Feet.	£.
Summer canals . . .	26,391,770	48,636	32,087,200	74,321
Flood canals	27,596,933	16,888	33,615,348	28,228
Drainage cuts . . .	5,112,300	6,525	10,943,000	5,125
New projects . . .	12,853,200	7,280	15,514,300	13,222
Total . . .	71,954,203	79,329	92,159,848	120,896

Prices of earthwork vary from 8*s.* per 1,000 cubic feet to £2 per 1,000 cubic feet, according as it is dry or slimy, when done by hand-labour under contract. The corvée clears the slime at a cost of £3 10*s.* per 1,000 cubic feet. Dredgers excavate the slime at a cost of £1 5*s.* per 1,000 cubic feet.

APPENDIX VII.—COST of CANAL CLEARANCES, and of NILE PROTECTION PER MILE of CANAL, and BANK, and PER ACRE IRRIGATED.

Second Circle of Irrigation.

Years.	Length in Miles.	Area Commanded.	Cost of Clearances and Protection.	Total Cost.	Cost per Mile.	Cost per Acre.
		Acres.	£.	£.	£.	s. d.
1883.						
Summer canals . . .	1,431	1,182,691	145,723	297,686	102	5 0
Flood canals	747		60,000		80	
Drainage cuts	174		0		0	
Nile banks protection .	265		91,963		347	
1884.						
Summer canals . . .	1,431	1,182,691	140,564	201,082	98	3 6
Flood canals	747		46,859		63	
Drainage cuts	174		0		0	
Nile banks protection .	265		13,659		52	
1885.						
Summer canals . . .	1,431	1,182,691	48,636	124,708	34	2 0
Flood canals	747		16,888		23	
Drainage cuts	174		6,525		37	
Nile banks protection .	265		52,659		200	
1886.						
Summer canals . . .	1,431	1,182,691	74,321	160,298	51	3 0
Flood canals	747		28,228		40	
Drainage cuts	174		5,125		29	
Nile banks protection .	265		52,624		200	

From the above it is evident that an additional land tax of 3*s.* per acre would suffice for the complete abolition of the corvée. This tax might be raised to 5*s.* in Menufieh and southern Garbieh, and lowered to 1*s.* in northern Garbieh. Lands which now pay a tax of £1 12*s.* per acre, and are rented at £4 or £5 per acre, and sold at prices ranging between £35 and £70, could easily bear an additional tax of 5*s.* per acre. Under the present system of corvée, all persons who own more than 5 acres pay nothing towards corvée work, while those who own less than 5 acres pay £3 per acre per annum towards corvée work.

[DISCUSSION.

Discussion.

Mr. E. Woods, President, said that the Paper contained an interesting account of works which had been carried on under the direction of Colonel Scott Moncrieff and his assistants. The Author had referred to the works carried on in connection with the Barrages, and the introduction of a complete system of irrigation in the Delta of the Nile. The estimate that would be formed of the value of the Paper would, he thought, be much higher than that which Colonel Scott Moncrieff had formed of the works under his charge. In a private letter which he had received in August last, Colonel Scott Moncrieff, after describing briefly some of his works, said, "They are no great engineering triumphs such as are described there, but very humble matter of fact works, which nevertheless have succeeded in giving many poor fellahs a water-supply they had never seen before. The fact is things were so hopelessly bad it was impossible for earnest working Englishmen not to make improvements, and though I have been, until the million arrived, desperately put to it for want of money, on the other hand no man was ever more fortunate than I have been in my officers, and I have been backed up to a great extent by the Egyptian Government. Nubar Pasha, especially, has given us constant support, and has showed a most enlightened desire to improve the country. One very able step he has recently enabled me to take is the partial abolition of the 'corvée,' an army of unpaid and unfed labourers, amounting to from eighty thousand to one hundred and twenty thousand men employed annually for half the year clearing the canals of silt, and doing all necessary earth-work. I told him that with £450,000 a year I could do all that was required by paid labour on the usual contract system, and that in a very few years, when we had remodelled the canals, I thought from £300,000 to £350,000 per annum would be enough. This year, in the face of all kinds of financial difficulties and opposition, he got me £250,000 to spend, and this has been an immense boon to the country." All must be glad to learn that after the strong opposition which had been made to the abolition of the "corvée," the Egyptian Government had, as stated in the newspapers of that day, consented to do away with it. He was quite sure the members would be unanimous in passing a vote of thanks to Mr. Willcocks for his able Paper. Mr. Woods.

Lieut.-General F. H. Rundall, C.S.I., R.E., remarked that the Nile Delta in its main characteristics was similar to the great deltas Lieut.-General Rundall.

Lieut.-General Rundall.

in Southern India, namely, the Godavery, Kistna, and Cauvery. In climate, however, the country was more like the Delta of the Indus, because in Sind, as in Egypt, there was practically no rain. The floods of the Nile came at a later period of the year than the floods of the rivers in India, probably owing to the extreme distance, 3,000 miles, which the water had to travel from the rain-fed sources. That fact had an important bearing on the growth of the food-crops, because the food-crops in a rainless country, being dependent entirely on irrigation, would naturally follow the seasons wherein the greatest quantity of water was brought down the river. The Author had confined his Paper to two provinces of what he termed the Delta, but, properly speaking, that term was rather apt to mislead, as the whole alluvial tract formed by the Nile during countless ages was the Delta. The tract of land referred to in the Paper was only that comprised between the two branches of the Nile. The flood-season food-crops in that tract were said to occupy about 590,000 acres, or about one-half of the total area. The winter food-crops, comprising wheat, barley, and beans, occupied 1,000,000 acres. If the same proportion were followed out through the whole tract of Lower Egypt, about 2,750,000 acres would be devoted to the growth of the staple food of the agriculturists. The population of Egypt was reckoned at about six millions, and it would therefore appear that an acre of land supported two individuals. In India it was generally estimated that an acre would support one person; but, taking into account the additional food-crops grown in winter, the result in Egypt was much the same. The first point to be considered with regard to irrigation was the chief object for which water was wanted, and that, in a rainless country, would naturally be the growth of the food-crops. It was, therefore, necessary to consider the quantity of water available at different seasons to produce those crops. During the season of high flood there was a superabundance of water, and in the winter season the supply varied from 25,000 to 55,000 cubic feet per second. It was not stated in the Paper what quantity of water was necessary to raise the respective crops; but it might be taken that the quantity needed in Egypt was very similar to that required in Upper India, where, under a carefully-managed system, 1 cubic foot per second was sufficient to raise food-crops for 200 acres. Taking the lowest of the two winter discharges, namely, 25,000 cubic feet per second, there would be sufficient to raise the food crops over the whole 5,500,000 acres; therefore the difficulty of a limited supply of water practically did not exist, and a great burden was taken from

Lieut.-General Rundall.

the shoulders of the engineer. The Author had mentioned eight problems to be solved by the engineer, one of which was the strengthening and securing of the Barrages so as to ensure a constant water-level during summer. Those Barrages were not of the same style of work as river-weirs in India. The latter were formed of a solid wall right across the river, pierced at intervals with sluices. The Barrages in Egypt consisted of platforms laid across the river on which piers had been raised, and arches had been thrown, so that the flood could pass through at its highest level. That was certainly an advantage, since it conveyed away the deposit and prevented the matter held in suspension from being deposited up-stream in the river. It had, however, one great disadvantage, requiring as it did the manipulation of a large number of heavy gates which had to be raised and lowered continually, in order, at certain stages of the river, to maintain the proper level for the water in the canals at the respective seasons. When he was in Egypt he was asked by the Khedive to look at the Rosetta Barrage, which was then in a very unsafe condition, and to suggest what could be done to render it safe, and capable of performing the work for which it was required, but which it had never as yet fulfilled. The particular danger to which he found it exposed was that the weight of the platform was not sufficient, or rather that there was not sufficient margin to resist the pressure of 14 feet of water that it was contemplated to raise on it, when on the upper side the water was raised to the full height, and on the down-stream side the Barrage would be comparatively dry with no water at all on the flooring. He therefore thought that it would be better to add to the weight of the platform by covering it with 1½ foot of ashlar, and also, in order to prevent leakage under the work, to have deep curtain-walls above and below—a precaution always adopted in India. He gathered from what had been stated that that had not been carried out, and that it had been thought sufficient to rely entirely upon extending the "talus" below, which was, of course, a good precaution. But weirs of all kinds were exposed to the very dangerous action of lateral and cross currents, and by the continual alteration of the sectional area of the river, and of the form of its cross-section, especially as those currents were generated during the time of flood, when it was impossible to detect what was taking place. Deep holes were formed above and below; and as the floods subsided the river-level on the lower side sank, and the greatest pressure of water was then brought to bear upon the work. It sometimes happened in consequence that the weir itself stood merely on a mound of sand with a deep hole

Lieut.-General Rundall.

above and below, and should any percolation then take place under the work from the pressure of a head of 14 feet of water, it was as likely as not that the sand would be moved and the weir subside. There were often instances of that kind occurring in delta works, and recently there had been a striking instance on one of the headlocks of the Godavery weir, which had stood for forty years, but suddenly gave way without any warning. The only remedy against such accidents that he could think of was the construction of curtain-walls. He had already conferred with Colonel Scott Moncrieff, and had given him all his papers and suggestions on these and other measures, to make such use of as he pleased. Allusion was made by the Author to training walls and spurs in order to regulate the main fair-way of the river track on to the Barrages. Training was a most important work, and it was one which received constant attention in India; if neglected it was likely to produce disastrous consequences to river weirs. It was stated in the Paper that the material used for the spurs and training works was stone; but experience in India showed that stone was not the right material. It was better not to divert the current of a river suddenly and rudely, but rather to coax it. The plan adopted in Tanjore and other districts, was that of open pile and brushwood work, which allowed a sufficient check in the current to cause large deposits on the up-stream side, and by flowing gently through the brushwood to deposit a smaller quantity of silt on the lower side. He was once able to divert in that way a very serious erosion in a part of the Ganges at the town of Rampore Bauleah, where the bank was carried away ½ mile in width and 2 or 3 miles in length, by simply using brushwood-and-pile spurs. In rivers where the material of the bed was so fine, it was very easy to divert the stream and to make it carry the silt in suspension to the place where it was wanted. With regard to the suggestions respecting basin-irrigation, he did not feel sure that he could agree with them. No doubt the deterioration of land mentioned by the Author, in the lower part of Egypt, had been occasioned by the construction of dykes to keep out the floods; but when raising embankments it appeared to have been forgotten to insert the necessary sluices for distributing the flood-waters, at the time when the river rose above the surface of the country. Had that been done the flood-waters would have been admitted over the highest levels, and could have been allowed to remain on the fields as long as was necessary. He was afraid it would not answer to establish a system of river basins in Lower Egypt, in a comparatively thickly popu-

Lieut.-General Rundall.

lated country; but if by the construction of the basins was meant merely the flooding of poor land for a certain number of days in the year, and collecting the deposit, it might be a good and real remedy for restoring fertility to the soil. The removal of the apex of the Delta, to a point 2 miles above the site of the Barrages, for the purpose of ensuring a better regulation of the two branches of the river, and a more equable division of its volume after the floods had subsided, was a decided improvement. When General Rundall visited the Barrages ten years ago, the division of the river was immediately close to the head of the Central Delta Canal, the objections to which he pointed out at the time, and which were subsequently confirmed by Sir Charles Hartley. One of the great difficulties encountered in irrigation canals was the deposit of silt consequent on the sudden change in velocity. The quantity of silt carried in suspension varied greatly in different rivers, and at different stages of the flood in the same river. The proportion in the Nile during high floods was, he believed, $\frac{1}{1,100}$ of its bulk, which was about the same as that carried in the rivers Godavery and Mahanuddy, but much less than that found in the Kistna and Indus, the quantity in the latter amounting to nearly $\frac{1}{250}$ of its bulk. So long as the velocity in the canal could be kept tolerably uniform, the proportion of silt transportable at that velocity would be carried forward to the fields. The greatest amount of deposit usually took place within the first mile of the main canal, and one of the suggestions made to obviate the inconvenience of the closure, in order to remove the silt, was to have a large basin at the canal head twice the width of the canal itself, in order to form a trap for the silt, and facilitate its removal by dredgers, and thereby prevent the necessity of closing the canal and stopping the navigation. When the construction of perennial canals in Sind was first attempted, in supersession of the old inundation canals, which were of the same type as the canals in Upper Egypt, very great inconvenience was experienced by the enormous deposits of silt above and below the regulator. The experiment was tried of taking in the water over the gates instead of under them, with the idea that less silt would enter the canal. How far the experiment there was successful he had not yet heard; but in another instance, in one of the tidal canals from the River Hooghly, which also carried an enormous amount of silt, a similar experiment was found to be successful in reducing the quantity carried into the canal. The expedient of having flood canals separate from the summer canals, with a view of dealing with the silt difficulty, had never been adopted in the deltaic system in India, for the reason that the

Lieut.-General Rundall.

flood season there was likewise the height of the cultivating season, when the greatest breadth of land was planted with food-crops, and the largest volume of water was required for their irrigation. In Egypt a different condition seemingly prevailed, the greatest breadth of cultivation being during the winter months while the river was subsiding. In the tidal canal which connected Calcutta by the River Hooghly with the Orissa Canal system, and was a purely navigation line, the expedient of feeding the main line from a small parallel channel, which received the silty water from the estuaries direct, had been tried, with the object of forming a trap for the silt from which its removal could be easily effected without resorting to a closure of the main line as had hitherto been unavoidable. Of course a diminished quantity of silt must still enter, but this would probably be easily removable by dredgers. It could not be gathered from the Paper whether the idea of separate or supplementary canals for the flood waters was a modern idea, or whether it was only a revival of an ancient method; but under the particular circumstances obtaining in Egypt it might be a practicable solution of dealing with the silt difficulty, which was a very serious one, and reminded him of a remark once made by an old irrigation engineer in India, that he believed when he died the letters S I L T would be found engraven on his heart. He was glad that the subject of navigation works in Egypt had been taken up, as it was a matter of great importance. The cost of transit had been one great burden from which Egypt had been suffering for a long time. He did not think any system of land transport could be introduced into the Delta which would supply the place of cheap water carriage, so essential for conveying agricultural produce, not only from the interior to the port, but inland as well. Finally, when all the main works had been constructed, there came the important point of managing the distribution of water in detail, which in Upper India was called the administration of the irrigation. He was quite sure it could not be left in better hands than those in which it had been placed. The officers who had come from Upper India knew their work well. It was a branch of duty that could not be well criticised on such an occasion, because every country had its own particular way of distributing water, and it was necessary also to study and respect ancient customs and prejudices. The engineers now employed had had great experience in irrigation works in India, and would, he believed, confer an enormous boon upon Egypt. The Khedive and the Government were to be very much congratulated on the selection that had been made, for in a very short time order had been evolved out of

chaos. The people themselves were specially to be congratulated on the abolition of that burden of forced labour which had oppressed them for so many years, and which, he believed, mainly at the instigation of Colonel Scott Moncrieff, had now been abrogated by the decree of the Khedive. Lieut.-General Rundall.

Lieut.-General J. MULLINS said that the field of irrigation in the Delta of the Nile differed very much from that part of India with which he was acquainted, because in Egypt there was a very small proportion of rice irrigation. The crops for the most part were what would be called in India dry crops. The summer rice crop in the portion of the Delta referred to in the Paper occupied only 30,000 acres, while the winter, or flood crop, occupied 35,000 acres. The value of the crops, in what might be called the Central Delta of the Nile, was very much greater than that of the irrigated crops in India. The Author had mentioned that the rice crop was, generally speaking, a poor crop. There was one part of it which in the summer irrigation yielded about £7 an acre, the remainder yielding only £2 an acre. In Southern India the value of the rice crop might be generally taken at £2 10*s*. an acre. The system of separating the flood irrigation from the summer irrigation was no doubt necessary, because the supply required in the floods was about 17,000 cubic feet per second, whereas for summer irrigation only about 4,500 cubic feet were required. There was, however, probably some difficulty in supplying the heads of the canals from the river direct, and if, as was probable, the Damietta branch was liable to considerable alterations in its deep bed, there would be a risk of shoals opposite the heads of those canals. It was not stated in the Paper whether it was intended to carry out any complete system of regulation of the flood-canals. The higher lands in the Delta would probably not suffer if the floods were comparatively unregulated, because all the surplus water would be drawn off; but that might complicate the reclamation of the lands which were on a lower level, and render their cultivation more difficult than would otherwise be the case. Of course, were the main canal capable of carrying the large supply of water required for flood irrigation, it might be more advantageous, especially as it was said that there was no deposit of silt with a velocity of 2 feet per second, to have the whole under one complete system of regulation. He did not quite understand the details of the system of basin irrigation mentioned in the Paper. In Upper Egypt, he judged from the comparatively short time which it took to relieve the lands of the water kept upon them for the purpose of depositing silt, there were considerable facilities for getting rid of the water when no longer required, Lieut.-General Mullins.

Lieut.-General Mullins.

after it had become clear. In the tracts of land referred to by the Author, amounting to nearly 600,000 acres, near Lake Borillos, and in the northern part of the Central Delta, he did not know whether there would be the same facilities. That part of the country was apparently very flat. If that large area could be submerged rapidly, so as to distribute the silt from the water pretty equally over the surface; and if as soon as that was done the water could be discharged rapidly into the river or into drainage-channels leading into the sea, it would seem that nothing could be more advantageous than the construction of the basins proposed by the Author. He should doubt the feasibility of introducing basins in that part of the Delta which had been irrigated under a very different system for many years, where villages and private property of various descriptions existed, which would be submerged for a considerable time; but there could be little doubt that the introduction of basin irrigation on a large scale, where the land was at present barren and valueless, would be a very great advantage. It was extremely praiseworthy that the engineers who were now in charge of the works, and who had only been there since 1884, had done so much in so short a time; and they must have exhibited considerable tact, as well as engineering knowledge, in being able to carry the Egyptian authorities with them.

Mr. Anderson.

Mr. W. ANDERSON (of Erith) estimated very highly the value of the Paper. The only regret which he felt was that the Author had, from his position or from his desire to speak only of what he personally knew, described chiefly what had been done in that comparatively small portion of the Delta, which had come immediately under his own supervision. It would have been of great value and importance, not only as a matter of engineering interest, but as a matter concerning the relations of this country with Egypt, to have had developed the whole plan which Colonel Scott Moncrieff and the Egyptian Government had decided upon for what he could not call less than the regeneration of Egypt. It so happened that Mr. Anderson was professionally interested in about 21,000 acres of land, lying in the waste belt, the part which skirted Lake Borillos, close by the Damietta branch of the Nile, and he could bear testimony to the enormous improvement which had taken place in it since the British occupation of Egypt. It was difficult to describe the effect of the confusion caused by the incompetence of the administration, the rapacity and greed of the native magnates, the sheiks and pachas, who were practically owners of the land, and managed it for their own advantage. There was no such thing as regularity in the administration of the water-service;

Mr. Anderson.

whatever was done by the powerful and wealthy was done to suit their particular interests, with a total disregard not only of the general welfare of the Delta, but even of their weaker neighbours. The British occupation, and the advent of Colonel Scott Moncrieff and his able staff, trained in the administration of similar works in India, at once altered that state of things. As fast as circumstances would allow, and money could be obtained, plans were carried out which appeared to have been matured with a promptitude which showed that the men in charge were masters of the situation, and he ventured to say that this boldness and readiness would some day excite the admiration of those who would live to see the results, which would be attained if those officers were left to carry out the work they had commenced. It was an act of extraordinary boldness on the part of Colonel Scott Moncrieff to make up his mind, before even his first year of office had been completed, that the Barrage should do its duty—a determination which no one had ventured to form for the forty years which had elapsed since its construction. With the caution and prudence which characterized true boldness, he attacked the problem, and he was now able to maintain 10 feet of water where barely 18 inches had been maintained before, the consequence being, as he himself could testify from personal experience in that unfortunate belt of land in which he was interested, that whereas lack of water was common before, it was now no longer heard of. An abundant supply was sent down, sufficient for all the needs of irrigation, and he thought that if time enough were allowed for carrying out the plans that had been laid down for improving the drainage and the inland navigation, the country, which must at one time have been densely peopled and very fertile, would have its fertility restored, and the land, which could not now earn even 10*s.* an acre to pay the taxes, would once more be able to support a teeming population. It was difficult for those who had not seen the Nile, to form an adequate idea of the enormous amount of deposit it brought down. He exhibited two specimens of water taken on the 20th of January, that was some three months after high water, from the river at Cairo. It would be seen from one bottle how it was heavily charged with mud, and it was easy to imagine what it would be when the river was in flood, bringing down all the fertilizing matter from the upper reaches. The water would not precipitate in any reasonable time, and it could not be filtered; it therefore carried all its fertilizing properties with it, as far as might be desired, provided only the precaution was taken of keeping up the current in the canals at such a rate that the silt would not deposit.

Mr. Anderson. The second bottle contained a specimen of the same water rendered perfectly bright and clear, by treatment with iron on the same system as that carried out at Antwerp. The contact with the metal seemed to have a curdling effect on the suspended matter, which enabled the water to be filtered quite bright through only 3 inches depth of sand. The great feature of the mismanagement of Egyptian irrigation had been the allowing of deposits to accumulate in the canals, to be removed afterwards at enormous expense, instead of being conveyed at once on to the land, there to produce the abundant crops which it was capable of nourishing. The members were not in the habit, in that Institution, of giving way to sentimental enthusiasm; but if there were a subject on which they might be allowed to be enthusiastic, it was the regeneration of Egypt at the hands of the engineer. In a Paper which he had contributed to the Minutes of Proceedings,[1] after a journey to the very portion of the Delta which the Author had described, he ventured to predict that it would not be by acute financial measures or political combinations that Egypt would be drawn out of her troubles, but by the science and skill of the engineer; and he could not help thinking that if the work were allowed to continue long enough (the Author had estimated twelve years as the time necessary to complete the regulation of the Nile), British reform would take root so deeply, that it could not be upset by the natural enemies of everything like order and progress; and the expenditure which England had been making so lavishly would be abundantly recouped. Another wreath also would be added to the many laurels with which this country was already crowned, since it would be instrumental in abolishing a most horrible species of oppression—that of forced labour, or corvée. Under that system the unfortunate natives were periodically dragged from their homes, separated from their families, and sent to distant places, sometimes never to return; they were fed in the most miserable manner upon dry bread, and forced to work upon canals in which they had not the slightest interest. Neither age nor sex was a protection, and those entrusted with the administration of the service enriched themselves by the money paid by the wretched fellahs to purchase exemption. The number of men called out every year was about one hundred and sixty thousand.[2] Yet within the short space of three years British engineers had suc-

[1] Vol. lxxvi. p. 346.

[2] Report of the Ministry of Public Works on the Irrigation of Egypt, and an examination of a proposal relating to it. Cairo, 1883. Abstracted in Minutes of Proceedings Inst. C.E. vol. lxxvii. p. 425.

ceeded in so arranging matters, that the corvée was practically done away with; and it would be absolutely abolished were it not for the under-current of opposition (the source of which he need not mention) against everything originated by England which would have the effect of sweeping away long-standing abuses. He believed that, in a year or two, the corvée would be a thing absolutely unknown, and that great and desirable reform would be produced by those who had charge of the engineering of the country. It was a marvel to him that any one could be found, who professed to have the interests of liberty, freedom and humanity at heart, who would recommend the abandonment of a country in which so great a work had been begun. The estates in which he was himself interested were not now capable of paying the taxes; but he, and those with whom he was associated, had faith in Colonel Scott Moncrieff and his staff, that they would hold on in the sure hope that, if they were only left in the district, and the British rule continued, those properties, now valueless, would prove to be as valuable as any agricultural land in the country. Mr Anderson.

Mr. F. G. M. STONEY said that he had devised some appliances which he thought were superior to those which had been employed in connection with the Barrages. He had been much struck with the account of the grating placed on the floor of the Barrages, to allow of sufficient current, when the sluices were closed, to prevent a deposit of silt immediately behind them. He had himself seen several feet of silt deposited in a single night behind such sluices. Those persons who put them up were pretty well aware that they were very difficult to manipulate, and that they could not be opened and shut in a moment; they therefore left permanent openings, which he called uncontrollable. What was wanted in those works was some kind of controllable Barrage which should be under command in all circumstances. Such appliances were to be had, and were in successful operation. Unfortunately, they were too large to bring to London, and it was very difficult to get men to travel a few hundred miles to look at them. They might, however, be seen at the Lough Erne drainage works. The sluices had a clear span of 30 feet, and were 14 feet 6 inches deep, the water sometimes flowing over the top. He had worked them by hand direct when there was a head of 16 feet of water upon the gates, and it was practically dry upon the other side, and he was never able to feel any difference in the pressure when the gates were worked in air, and when worked with a full head of water on them. Such sluices might be made up to spans of 100 feet. With the small power necessary to manipulate the gates at all times Mr. Stoney

Mr. Stoney. there was not the slightest difficulty, whatever the extent of the span. If the sluices were counterbalanced, as in the case of several that he was at present making, they might be manipulated by one man with practically no gear whatever. Some that he was constructing having spans of 25 feet could be moved like a sash. Several years ago, Mr. Richard Foley, of the Public Works Department in India, made for the New Jaoli Lock on the Ganges Canal four sluices on free rollers, from plans sent him for the purpose by Mr. Stoney. These sluices were actuated without lifting screw or rack, a horizontal axle was simply carried on a pair of A-frames overhead. A pair of chains passed over two small chain-wheels on this axle, the chains carried the doors at one end and counterbalances at the other, and the sluices were actuated with the greatest ease by a simple hand-wheel, resembling a tiller-wheel keyed direct on the axle. Mr. Stoney was afterwards informed, by an engineer who had witnessed the occurrence, that a great quantity of silt was suddenly carried down during the night, and the locks were all but filled up; the ordinary sluices on a neighbouring lock could not be worked, but the sluices on free rollers came up through the silt with no marked difference of resistance. This was an experience of value in considering large sluices for Egypt.

Sir Frederick Bramwell. Sir FREDERICK BRAMWELL, Past-President, said he did not know a much more mournful sight than that which was presented by the Barrage when he saw it six or seven years ago. It was, no doubt, a grand work thrown across the two streams, but it was an absolute failure. Looking along the work over the Rosetta branch the curvature could be seen in a line which he was told was produced by an attempt to subject it to pressure that it was not originally intended to sustain, and that pressure had to be reduced. On the Damietta branch he believed that the sluices had not been put in at all. On the Rosetta branch the sluices were of a very peculiar character, being hinged by radial rods to a sort of central pin composed of a succession of cylinders of varying diameters united with some kind of diaphragm, he believed, with the notion that their weight should be water-borne, and that thereby they might be readily manipulated. But as the work then stood it appeared to be a practical failure. He might, perhaps, be allowed to mention an implement that had attracted his attention; it was an equivalent for a diving-bell, and was known as the *bateau plongeur*. There were two of them, one larger than the other. There was a vessel, having a cabin, which was airtight. On the floor there was a very considerable oval wrought-

iron casing, which was slid through the opening and coupled to a sort of curb that rose round about it by folded leather. The casing could be lowered to the bed of the river, and when so lowered, on air-pressure being put into the cabin, the water was driven down, and while in the cabin there could be seen through the opening a sort of well of water being driven out, and one could go down and do the work at the bottom. The depth of it would be regulated by appropriated tackle, the joint being maintained by the folded leather. In that way they had a diving-bell, the upper part of which was above the surface of the water, and was associated with certain means of comfort and convenience, the top of the diving-bell ending in a cabin, so that it was not necessary to get into it in the ordinary manner. It appeared to be a very ingenious appliance, and the two that he saw were of considerable use in the subaqueous examinations of the foundations of the Barrage. He was not fortunate enough to see them at work; but he was struck by them as instances of another mode by which subaqueous works at no great depth could be carried out with considerable ease and rapidity. Sir Frederick Bramwell.

Mr. J. Compton-Bracebridge said that his only claim to be heard was his having been employed in Egypt in visiting the unlucky properties to which Mr. Anderson had alluded, but he desired to make one remark which he thought was called for by observations that had been made as to the effect of the effluent water from the upper part of the Delta on the low-lying lands near the lakes. The lakes were really arms of the sea, because in almost every case there was a small outlet to the sea. The level of the water in the lakes was, he believed, higher than sea-level. Just before he left Egypt, six weeks ago, the Public Works Department made some inquiries to ascertain what effect the lowering of the level of the lakes would have on the towns and villages on their borders. He believed that it would have a considerable effect, because the only water-supply of those towns was brought in boats, and the lakes being very shallow at the edges, any lowering of the water-level would materially increase the distance over which the water would have to be carried from the boats for the use of the people. The enquiry showed that the Public Works Department was evidently thinking of dredging out the narrow outlet to the lakes, and thereby lowering the level of the water, which would produce a greater fall for drainage, and would increase the cultivation of the low-lying land on the edge of the Delta. Mr. Compton-Bracebridge.

Mr. W. Anderson had omitted to notice one point arising out of the remarks of General Rundall with reference to basin irrigation. Mr. Anderson.

Mr. Anderson. He had noticed, in traversing the portion of the Delta which the Author considered specially suitable for that mode of irrigation, that nearly all the villages were built on hillocks. It seemed as if the villages, which no doubt had existed from time immemorial, had been purposely placed in such situations as to render basin irrigation possible, and he did not well see how the salt, which now encumbered the land, and in places rested like snow upon the ground, was to be got rid of except by flooding the whole area of the fields at high Nile, letting the water drain through, thus washing out the salts and leaving the deposit of rich mud on the surface. He did not think there was any other method that would restore the land to the fertility which evidently it had at one time enjoyed.

Lieut.-General Rundall. Lieut.-General F. H. RUNDALL said that the same thing had occurred in almost all the deltas in India, especially in the Godavery District, in the neighbourhood of a large lake situated at the water-sink of the Rivers Godavery and Kistna. There the efflorescence on the soil was in large quantities, but as soon as the canals were excavated, fresh water laden with silt was sent down during the flood season when all the lands were flooded, not for any length of time, but periodically, and resulted in the finest crops being afterwards raised on that very soil.

*** The Author, being in Egypt, has not yet had an opportunity of replying to this Discussion.

Correspondence.

General Cotton. General Sir ARTHUR COTTON, K.C.S.I., stated that before he left India he had come to the conclusion that cheap carriage, which could only be obtained by means of water, was of even greater importance there than irrigation; and he felt assured that in Egypt, even though the distances were so small, the water transit was an essential part of the work of improving the Delta. Of the immense capabilities of the Delta he had no doubt, and, indeed, what had already been accomplished by Colonel Scott Moncrieff with such insignificant means, was a proof of that.

Mr. Evans. Mr. C. T. EVANS was predisposed to believe that the basin system advocated by the Author was calculated to prove eventually injurious rather than beneficial to the soil, especially where there was not fall enough to admit of the water flowing off quickly after deposit of the matters held in suspension. The land must, he

thought, eventually become water-logged and unproductive. He gathered from the Paper that, under the basin system, the country would be flooded for from one month to two months; the soil would thus be saturated, and in a low-lying flattish country would practically remain so. Moreover, as regarded Lower Egypt, he thought that, owing to the basin system in Upper Egypt, the flood water both arrived too late, and was deficient in the material which was said to confer productiveness. The conditions, therefore, under which basin irrigation would be carried on in Lower, were much less favourable than they were in Upper, Egypt. He was strongly of opinion that an extension of the canal system, accompanied by efficient drainage, was the only safe one to adopt for Lower Egypt. This of course would not succeed without strict administration and regulation, and such, he gathered, did not exist at present, the landowners higher up taking water at will at the expense of those lower down. As regarded navigation, he would do without it, and have light railways or tramways for communication and carriage. Navigation and irrigation were incompatible. Mr. Evans.

Lieutenant-General J. G. Fife observed that more than thirty years ago he visited the Barrages, and was shown over the works by Mougel Bey, who at that time was engaged in strengthening the talus, or apron, by lowering masses of concrete from boats to the bed of the river, which had been previously dredged. The concrete was in boxes with movable bottoms; these were opened at the river bed, thus allowing the concrete to pour out and adapt itself to the cavity, to be filled before setting. Mougel Bey did not then appear to have any doubt as to the success of the work. On two points only had he some brief remarks to make. In the first place, the Author thought it would be possible to regulate the river floods by admitting them into the basins, and allowing the water afterwards to return to the river to maintain the supply after the flood had passed off. This was a large question, and, without figures showing the capacity of the basins and the levels, it was impossible to come to any conclusion. The difficulty to his mind was to deal with the vast body of water quickly enough; for it was not as if there was a weir across the Nile in Upper Egypt, and the object was merely to divert the stream. Without elevating the river above its natural flood level, an enormous volume of water had to be drawn off. Secondly, without in the least underrating the advantage of reducing the deposit of slime in the canals in Lower Egypt, both to save expense of clearance and to increase the efficiency of those works, he thought that too much Lieut.-General Fife.

Lieut.-General Fife. credit was given to the fertilizing effect of the slime, and that it would be found that the grand cause of the deterioration of the soil on the regularly cultivated lands was simply over-cropping, and want of plenty of manure and judicious rotation of crops. Commerce had stimulated production beyond the powers of the soil. In Sind, a province watered by the Indus, and very similar in character to Egypt, the canals had such a velocity—generally over 2 feet per second—that the slime was carried on to the fields, the sand only, as a rule, being deposited in the canal. Yet it was found that after a crop of maize, which sometimes attained a height of 8 to 10 feet, the land had to be left fallow from one year to three years. Rice lands properly irrigated also required to be left fallow, or to have plenty of manure. Rice lands not regularly irrigated, but from their low level completely flooded, were cropped every year, but the crop was an inferior one. Rice in such a situation grew as much from the water as from the soil. The water gradually rose during the inundation period, June to September, and in places attained a depth of 4 or 5 feet; but the rice rose with it and kept its head above water, and was eventually reaped with the aid of boats.

Sir Charles Hartley. Sir CHARLES A. HARTLEY, K.C.M.G., observed that the Paper was naturally of great interest to him, as he had ascended the Nile in sailing vessels from the Damietta mouth to Assouan in the winter of 1860–61, and in the spring of 1877 had been invited by the Ex-Viceroy of Egypt, Ismail Pasha, to visit the Barrage, in order to report to His Highness on the projects of Mr. (now Sir John) Fowler and Mr. Gatget (a distinguished engineer, representing the Fives Lille Company in Egypt), for utilizing the Barrages to the best advantage. As this great work was the most prominent feature in the Paper, he would quote the following passages from his report to the Ex-Khedive in June 1877, three months after he had visited the ground in company with Mr. Gatget and Ali Pasha Mabarah, the Minister of Public Works at that period:—"After a close study of the subject in all its bearings, I agree with Mr. Fowler and Mr. Gatget in their opinion. Firstly, that it is more desirable to utilize the Barrage with its bridges, locks, canals, &c., than to resort to other proposed solutions, such as the more costly expedients of establishing a 'grand canal de dérivation' high enough up the Nile to bring its waters at the low-water season to the required level at the head of the Delta; of constructing an entirely new barrage at some point between Cairo and the existing work, or of gaining the same end by means of pumping only; and, Secondly, that, the failure of the Barrage is due to

defective foundations and not to any violation of general principles in the original design. Disbelieving in the efficacy of any means of effectually repairing the foundations, Mr. Fowler and Mr. Gatget recommended the construction, across both arms of the river close to the Barrage, of a wall of rubble masonry founded at a great depth, and designed so as to remove all future anxiety regarding the effects of infiltrations either through or below the masonry, or rubble, of the existing work. There is, however, a notable difference in some respects in the two projects. Mr. Fowler proposes to complete the sluices of the existing Barrage, to construct a new set of sluices on deep foundations immediately *below* the down-stream edge of the present foundations, and to arrest the erosion of the river bed below the Barrage by protective works of an important and adequate character. As, in Mr. Fowler's opinion, it would be inexpedient to expose the foundations of the present work to a greater chance of undermining than they have hitherto encountered, the future head above the old works would be limited to 1½ metre, and, a lower curtain wall being constructed, there would be no danger of the existing foundations being undermined. The new sluices would be founded on a continuous solid wall 8 metres thick, carried down to a depth of 18 metres below low Nile—deep enough to avoid all risk of sand being carried under it by the difference of hydraulic pressure on its front and rear sides, and to prevent undermining by the severe action of the under current produced by falling water. The river bed below the Barrage would be covered with a broad mass of rubble, incorporated with which would be two lines of heavy béton blocks. The top surface of these defensive works would be kept 8 metres below low Nile in order to obtain an efficient water cushion for the falling water. Immediately in front of the wall would be a line of béton blocks of sufficient weight to resist removal by the under current, and to form with the rubble a solid abutment to the whole structure. It has already been observed that the submerged foundations of the Barrage are of less weight than the head of water it was intended to bear when it was first designed, and that, therefore, the bed of the river being exceedingly mobile and porous, grave doubts might have arisen as to the ultimate stability of the structure, even supposing the béton had been sound throughout. In considering the question of head, it should be borne in mind that the irrigation canals, when the Barrage is finished, will withdraw 230 cubic metres per second or two-thirds of the minimum low-water flow of the Nile, and that consequently the present low-water level below the Barrage, when

Sir Charles Hartley.

Sir Charles Hartley.

the maximum contemplated head of water has been obtained, will be considerably lowered, so that, including the height of water flowing over the top of the sluices, the difference in level above and below the gates would occasionally be as much as 6 metres. Now, the weight of 6 metres of water being equal to 5·64 cubic metres of submerged concrete, and allowing a margin of safety of only 50 per cent., the foundations of the new work should be founded, irrespective of other considerations, at a depth of 8½ metres, to guard against all danger of the apron being blown up by the upward pressure of a possible head of 6 metres above the sluices. Unfortunately, however, another element, more dangerous than that of mere statical pressure, must be taken into account in dealing with the 'fine running sand' of which the bed of the Nile at this locality is said to be composed to an unknown depth, and that is the percolation of water underneath the foundations, by the action of which, if the foundations are not deep enough, the whole work is liable to be slowly but surely undermined. To check this percolation, the best plan, in my opinion, is to sink the foundations to such a depth as would cause the substratum to be less permeable by the pressure upon it of a massive wall of great weight, as proposed by Mr. Fowler. Mr. Gatget's project is to construct, at the distance of 40 metres *above* the old works a strengthening wall founded at a depth of 22 metres below zero—a depth which Mr. Gatget considers necessary in order to reduce the leakage under the wall to such an insignificant quantity as to be practically harmless. On this wall would be built sluices of sufficient solidity to resist the pressure of a maximum head of 5·80 metres of water. The space between the old and new works would be filled up by widening out the concrete and masonry of the existing platforms. It is incumbent on me to refer to the unsatisfactory condition of the *régime* of the Nile between Cairo and the Barrage, and especially of the reaches immediately above the latter. When I descended the river from Cairo on the 9th April in your Highness's steamer, the level of the water at the Rosetta Barrage, the sluices of which were closed, stood at 2·50 metres above zero on the upper side of the sluice gates, and at 1·75 metre above zero below them. The head of 1·75 metre was employed in feeding the central canal, and in scouring the Damietta branch, the sluices of which were open—otherwise the east channel below the Barrage, as well as above it, would have been completely dry at the then low-water stage of the river. This circumstance, and the fact that the large pool facing the upper side of the Damietta Barrage, would then have been a *cul de*

sac, except for the artificial current flowing from the Rosetta branch along the revetment wall which connects the two Barrages, at once convinced me, irrespective of the evident signs of the recent erosion of the left bank of the main stream, that the natural tendency of the river current is forcibly to direct itself more and more to the west. This, of course, is done at the expense of the Damietta branch as soon as the Rosetta sluices are lifted; and if the river is left much longer without control, the Damietta Barrage is liable to be left high and dry and the Rosetta Barrage outflanked or destroyed at no distant day. It is, therefore, urgently necessary not only to complete both Barrages according to the original design, but to regulate the flow of the river for a long distance up stream as well; for although the acquisition of the desired head of water would ensure a perfect control over the quantity flowing down each branch at low Nile, there would be no such control at high Nile, when all the sluices would be open. Consequently the construction of extension and substantial guiding works for some miles above the Barrage is absolutely necessary, to protect the latter against the dangerous effects of an uncontrolled current when the sluices are lifted." Sir Charles Hartley.

The Author stated that the severe action below the Barrage when a gate was lowered to its full extent, was found to be due to iron gratings or "windows" in the foundation, and not, as it had been supposed by the writers of the reports on the Barrage, to a honeycombed foundation. Sir C. Hartley now heard of these *open* gratings for the first time. Their existence was never mentioned by Mr. Gatget and the Minister of Public Works when they accompanied him to the Barrage; and in all his communications with Sir John Fowler and his staff, it was taken for granted that the alleged inability of the structure to withstand uninjured a greater head of water than 2 metres was solely due to the porous nature and insufficient depth of the foundations. This view was also confirmed as lately as 1883 by the Public Works Ministry, who then asserted that, owing to the defective foundations, any attempt to hold up the water beyond what was necessary to prevent the Nile from flowing altogether in the Rosetta branch, and leaving the Damietta dry, would lead to disaster. In describing the Rosetta Barrage, the Author stated that the left half of the platform was laid on loose sand, and the right half on loose stone, and that the whole barrier was practically watertight, owing to the excellent cementing properties of the slime deposit of the river. He further declared that all the water that escaped through the Barrage found its way through the iron gratings and not

Sir Charles Hartley.

through fissures in the concrete, as had been formerly supposed. This new and favourable view of the stanchness of the foundations induced Colonel Scott Moncrieff, when he took the direction of public works in 1884, to disregard the discouraging predictions of his predecessors, as well as the universal feeling of distrust which followed the giving way of some of the work when it was first tested, soon after its completion in 1862, and to try the bold experiment of increasing the head of water against the Rosetta dam to 10 feet, and against the Damietta dam to 5½ feet. By way of precaution, however, he closed the gratings, and added considerably to the width of the rubble bank immediately in rear of the submerged platforms, in the manner described by the Author, so as to oppose more weight to the proposed augmented horizontal thrust against the structure. The result of this experiment had been entirely successful, and when in Egypt two years ago, and also elsewhere since that time, he had heard many distinguished engineers (French and Italian, as well as English) who had made the question of the Barrage a special study, express their warm admiration of Colonel Scott Moncrieff's famous achievement in adding so greatly to the utility of the Barrage in so short a time and for so little money. It now remained to be seen what effect would be produced on the work when the desired head of 5 metres, in two drops of say 2½ metres each, had been obtained. For his own part, he would have preferred the adoption of a plan which, while retaining the principle of a double drop, would have provided for the establishment of new foundations for a second or supplementary dam below the existing one, founded on a solid wall of masonry at such a depth as would have made the structure *absolutely safe for all time.* Nor, in his opinion, would the comparatively large expenditure required for such a work be difficult to justify, for not only did the successful irrigation of the Delta at low Nile depend on the absolute stability of the structure, but the retention of the head of water at the height originally intended was undoubtedly the best auxiliary for distributing the waters of the Nile in suitable proportions through its two deltaic branches. When the Barrage was designed by the French engineer Mougel Bey, in 1843, the chief flow was through the Damietta branch; and even in 1855, according to Linant Bey's Hydrographic Chart of Lower Egypt, the volume of water discharged in flood by the Rosetta and Damietta branches was 4,665 and 4,287 cubic metres per second respectively at high Nile. At the present time, however, according to the Author, the Rosetta had nearly twice the flood supply of the Damietta branch. This serious change in so

short a time, in the relative discharges of the two branches, was very significant of what might be expected to occur at the apex of the Delta, if efficient means were not speedily taken to regulate the volume of the main stream in such a way as to assure a constant and sufficient flow through the Damietta branch, the navigable channel of which, according to his information, had lately very sensibly deteriorated both in depth and width. In his Paper on "The River Nile,"[1] Mr. Baker gave a valuable tabular statement of the average discharge of water and solids per month, and in this Table it was specially worthy of notice: first, that in August the Nile conveyed three hundred times more solids in suspension than in May, although during the former month the volume of water discharged was only ten times greater than in May, the weight of solids in suspension to the weight of water being then $\frac{1}{21.000}$, whilst in August it rose to $\frac{1}{674}$; secondly, that in August, although the volume of water discharged was only one-quarter less than in October, the suspended sedimentary matter was three times greater in August (when the weight of sediment attained its maximum of 23,100,000 tons) than in October, when the discharge of water was greatest, although the solids in suspension had then decreased to 7,600,000 tons, the proportions of sediment to water being $\frac{1}{674}$ and $\frac{1}{2.640}$ respectively. This investigation afforded strong corroborative evidence of the importance of the Author's remark that in October the Nile water was diluted with the clear basin water of Upper Egypt, and it might be added of the Upper Nile, and completely confirmed his own experience respecting similar phenomena on the Lower Danube. As 300 cubic metres per second were already utilized in irrigating 1,155,000 acres in the provinces of Menufieh and Garbieh, and as the minimum flow of the Nile, 400 cubic metres per second, would be needed to irrigate 1,540,000 acres at low water when the Barrage was completed, the east and west provinces, which had an area of 3,960,000 acres (the total cultivable area of the whole Delta being 5,500,000 acres, or 8,600 square miles), must depend on the flood waters alone for irrigation. Consequently, as the Author had pointed out, the reclamation of Lower Egypt or the Delta by summer irrigation was impossible. The value of the Barrage, therefore, in utilizing the summer supply in the two central provinces was small in comparison with the full utilization of the flood-waters on the improved system of distribution introduced, and already so successfully practised, by Colonel Scott Moncrieff and his staff. This remark would have

Sir Charles Hartley.

[1] Minutes of Proceedings Inst. C.E. vol. lx. p. 373.

Sir Charles Hartley.

greater force when it was remembered that the flood supply of the Nile, during the five months of August to December inclusive (when the soluble constituents had the highest fertilizing power), carried in suspension 47,000,000 cubic metres of solid matter possessing extraordinarily rich fertilizing properties, as compared with 2,500,000 cubic metres of inferior fertilizing ingredients during the seven months from January to July inclusive; the proportion of solids to the weight of water being $\frac{1}{1{,}560}$ in the first period, and $\frac{1}{8{\cdot}270}$ in the second period, during the greater part of which the Barrage would be closed.

Thanks to British administration, and to the enlightened zeal of Nubar Pasha, the abolition of the corvée had at last been proclaimed throughout the land of Egypt. That cruel system, which kept alive discontent among the fellahs by compelling them to leave their own fields to toil for the State, was in full force in 1862, at which period he was informed on the ground, by an official high in office, that an average of one hundred and fifty thousand men were annually employed during four months of the year in removing silt from the canals, repairing the river banks, and in constructing new works. So lately as 1884 also, as stated by Mr. Cotard,[1] more than 10,000,000 cubic metres of silt were lifted annually from the canals in Lower Egypt alone, a work which required the calling out of one hundred thousand men during several months. With the system of hired labour now so happily introduced, and the recent greatly improved water distribution in Egypt, whereby according to the Author the silt clearances had already been reduced to one-fifth of what they were, these great reforms, together with the abolition of the corvée, which could only be accomplished by enormously decreasing the labour formerly required for the periodical cleansing of the canals, would be an immense boon to the cultivators of the poorer class, and would unquestionably have the effect of rendering the onerous land-tax of the Government less heavy for them to bear. The question of making the principal canals navigable, in order to convey the produce of the fields cheaply to market, was only alluded to incidentally by the Author, who inclined to the idea that light tramways would pay better, as "the work of combining navigation, drainage and irrigation, with their conflicting interests, is so difficult and costly." Without attempting to contest this view, he would merely remark that, wherever new canals

[1] Le Nil et l'Égypte, par M. Charles Cotard, Siège de la Société d'Études du Nil, 46 rue Cambon, Paris, 1884.

were made or old ones improved, it appeared to him very desirable, as a rule, that they should leave the river at right-angles and never obliquely in a down-stream direction, as in the case of the Behera and Charkieh canals immediately above the Barrage. Sir Charles Hartley.

The navigation of the Nile proper was a far larger question, and although the subject of river navigation hardly came within the scope of the Paper, he might perhaps be allowed to offer a few remarks on this interesting topic, as well as on the chief characteristics of the Nile, as compared with three other rivers of greater importance as navigable streams.

Relative Characteristics of the Nile, the Ganges, the Mississippi, and the Danube.

—	Length in Miles.	Drainage Area in Square Miles.	Annual Rainfall in Cubic Miles.	Mean Annual Discharge in Cubic Miles.	Mean Ratio.	Mean Weight of Dry Sediment to Weight of Water.
Nile . . .	3,300	1,293,000	892·1	22·7	39·3	$\frac{1}{1,900}$
Ganges . . .	1,680	588,000	548·8	43·2	12·7	..
Mississippi . .	4,190	1,244,000	673·0	132·0	5·0	$\frac{1}{1,500}$
Danube . . .	1,750	316,000	198·0	44·3	4·5	$\frac{1}{3,060}$

As the central and lower parts of the Nile flowed through an exceptionally dry and sandy region, it discharged, as shown on the Table, only $\frac{1}{39}$ of the annual rainfall on its catchment-basin, and as regarded ratio of rainfall to discharge, compared with other rivers, it was three, eight, and nine times greater than the Ganges, Mississippi, and Danube respectively. Again, although the Nile had about the same drainage area as the Mississippi, its annual rainfall was 30 per cent. greater, whilst its annual discharge was six times less than that of the "great father of waters." Compared with the Danube, the annual discharge of the latter was double that of the Nile, although the annual rainfall of the Nile basin was four and a half times that of the Danube. The perennial flow of the Nile was due to the magnificent lakes of Central Africa, which lay at its source; while its annual inundation was caused by the flooding of the Atbara and Blue Nile during the rainy season. These two tributaries (although almost dried up from the end of October to the middle of May, when mountainous Abyssinia was as

Sir Charles Hartley.

rainless as Egypt) were mighty streams from the beginning of June to the end of September, and the undoubted origin of the periodical inundations, the unfailing deposits, and the wonderful fertility of Lower Egypt. He would also cite some further examples, which proved that the Nile was essentially an anomalous river. When other great streams in Europe, Asia, and America were at their lowest, the Nile was in high flood, for it continued rising till October, when it reached its maximum height. Again, unlike every other river in the world, it rose every year, with marvellous regularity as to time and fixity of volume, and flowed for the last 1,600 miles of its course from the mouth of the Atbara (200 miles below Khartoum) to the sea, without receiving a single tributary. Finally, owing partly to the large deposit of alluvion on the land before the fluvial current reached the sea, and partly to the strong littoral currents which swept away the remaining deposits to the deeper parts of the Mediterranean, "The Delta," to quote the words of an eminent geologist, "now gains little or nothing on the sea, and the coast is changed but very slightly from what it was three thousand years ago."[1] The navigable channel of the Nile, from Assouan to Cairo, was deep enough all the year round for vessels drawing 5 feet, and from August to the end of January for vessels of 8 feet draught. In this respect, therefore, the Nile in its untrained condition from the first cataract to Cairo, 590 miles, was as good as that of the untrained Danube from Ibraila to the Iron Gates, a distance, however, of but 370 miles; whilst it compared very favourably with many artificially trained European rivers, where great expense had been incurred to obtain even a less depth than 5 feet over a considerably shorter distance. The existence of strong currents off the Delta seaboard would have been highly advantageous to the maintenance of deep water at either the Rosetta or Damietta mouth, where the depths were now only from 5 to 8 feet, if parallel piers had been constructed at either entrance on the system which had been so successfully carried out at the Sulina mouth of the Danube and at the South Pass of the Mississippi. So far as he could learn, there had never been a serious project having this object in view, and the facts that the construction of the Barrage itself manifestly created a permanent and very grave obstacle to the navigation; that the railway bridges below Cairo were only open once a day to shipping; and that heavy taxes were imposed on trading vessels,

[1] "Geology: Chemical, Physical, and Stratigraphical." By Joseph Prestwich. Vol. i. p. 86. 1886.

as was the case when he was last in Egypt, amply demonstrated that the idea of executing anything like a comprehensive project for the improvement of the navigable channel of the Nile, had never been seriously entertained by the Egyptian Government. In other words, that Egypt being emphatically an agricultural country, the improvement for navigable purposes of its great natural highway had always been considered entirely subordinate to the more pressing demands for efficacious and economical appliances for ensuring the due irrigation of the land at all seasons. Sir Charles Hartley.

Major-General P. P. L. O'CONNELL, R.E., remarked that whereas the operations included under the general term "irrigation" embraced the providing periodically of a fresh and well manured soil, as well as the watering of that soil either continuously or at intervals during the growth of a crop, the Upper Egyptian system was almost confined in winter to the first operations of providing a new well manured and saturated soil. He said almost, not entirely, confined, as probably there might be some subsequent watering. It would appear that of late years a system of summer irrigation had gradually been improved, if not absolutely perfected, in Lower Egypt, which provided the land with as much water as it needed, but gave it little or no fresh soil or manure. From the remarks recorded at the end of the Paper, it would almost seem as if the Author thought the deterioration of the soil, in Lower Egypt of the present day, was due to this improved summer irrigation. Doubtless he was quite correct in asserting that Lower Egypt wanted the slime of the Nile. But could this not be provided by opening out large canals from the river, and thus forming a flood-season system to be worked either together with or in continuation of the summer system? It was much to be regretted that this question had been overlooked for so long a time. It presented difficulties, which could probably be overcome only by skilful hydraulic engineers thoroughly acquainted with Egypt and the Egyptian system, but these would require time and money to work out a remunerative and otherwise satisfactory plan. In order to show the necessity for a special study of this great problem, he would draw attention to an existing successful system of irrigation, in which the original natural features were nearly similar to those of Egypt and the Lower Nile, but which could not be exactly copied, owing to the great differences in the present works of art in the two countries. He meant the system on which nearly the whole of Tanjore and a portion of the Trichinopoly district of Southern India were irrigated. In the Indian system the water was supplied by a river which divided Major-General O'Connell.

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Major-General O'Connell. into two branches at the head of the Delta, distant about 80 miles in a direct line from the sea, the left-hand branch being about 800 yards in width, and flowing over a bed having a lower level than that of the right-hand branch; so much so that a weir had to be constructed across the left-hand branch, in order to prevent the right-hand branch being silted up, and deprived of the water required for the irrigation of a large area of land. The Nile also divided itself into two branches, of which the left-hand one flowed over a lower bed than the right-hand one, but the artificial treatment of the two rivers had been very different. In the Nile, weirs had been run across both branches, and a main irrigation canal was carried between them in order to irrigate the land between the two branches. In the Tanjore and Trichinopoly system, the water was distributed not through a small canal, but the whole of the right-hand branch of the river, also about 800 yards in width, carried off the water for irrigation; and, except in heavy floods, the whole was distributed by a river system, the first branch being divided and sub-divided so that the water was spread over a large area, and the surplus entered the sea at many points along a length of 100 miles of coast. The earliest flood of the irrigation season was generally a small one, and the cultivators desired that it might be preceded by very dry hot weather, in order that the ground might have its surface cracked all over, and thus be prepared for the reception of the sediment brought down by the river, which contained vegetable as well as mineral matter. In heavy floods much of the water brought down the right or irrigation branch of the river, was returned to the left or drainage branch at about 15 miles below the primary bifurcation, over a large waste weir locally termed the "Grand Anicut." It would thus be seen that the Tanjore system combined the advantages of the Upper Egyptian system with that of Lower Egypt. One something like it, without being an actual copy, might perhaps be introduced in the Delta of the Nile. With respect to the question of the stability of the Nile Barrage, it would not be necessary to repeat the description of the works themselves, given in the Paper; but it might be useful as well as interesting to consider the mode in which a portion of the work was injured. The description of the regulation of the Barrage previous to 1884, and the resulting accident, seemed to be a perfectly correct statement on the part of the Egyptian foremen. Among the causes of the injury sustained by the Barrage should be mentioned the rapid current, not merely through the last openings, but along the face of the work from east to west. This current must have carried a considerable

Major-General O'Connell.

portion of the water flowing down the eastern half of the Rosetta branch over to the western side, and in so doing it must have removed a good deal of surface-silt and fine sand also from the bed in front of the Barrage, thus increasing the flow through the bed under the work from south to north; and as a greater scour was at the same time produced by the action of the water flowing on to the bed on the northern or down-stream side of the work, the velocity with which the water flowed through the bed was probably sufficient to remove material from under the flooring. When all the openings had been closed, a healing process would set in. There would be no more scouring, but on the contrary, a deposition of silt would take place, plastering over, so to speak, the wounds previously inflicted on the bed above the Barrage, and checking the under-current. How slight a current would suffice to remove portions of the bed, first on the down-stream side of the work and then beneath it, until hollows were formed under the solid masonry, might easily be conceived. It had been described by Mr. B. Baker[1] in the following terms:—"Borings to a depth of 100 feet show that the soil is light stuff which melts almost like sugar when in contact with water; so the present critical state of affairs requires no further demonstration." Possibly the subsoil might be of a similar character to a much greater depth, even so far from the sea as the head of the Delta; but the fact that the Barrage was still standing showed, that when the distance between the points at which the water forming the subsoil current entered and issued from the bed was sufficiently great, that subsoil, subjected as it was to the pressure of the superincumbent masonry, was very little disturbed by the water flowing slowly through it. Experience in this case, as in others, also showed that when the distance, between the points at which the water forming the under-current entered and issued from the bed, bore too small a ratio to the head of water above the work, the subsoil would be disturbed, and the work would in time be undermined. The stability of the work would, in his opinion, be increased by covering the bed of the Nile above the Barrage. This covering might be laid at a lower level than the crest of the platform on which the bridge stood. Its depth need not exceed 2 feet; its surface might be depressed somewhat on its up-stream side. It would not be required, perhaps, along more than one-third of the length of the work, if placed in front of the openings which were the last to be closed; but all details might safely be left to be settled by the

[1] Minutes of Proceedings Inst. C.E. vol. lx. p. 374.

Major-General O'Connell.

experienced officers now in charge of the works. He should only add that the views which he had here expressed were not merely conjectural. They were the results of observations made, it was true, on rivers whose beds contained coarser sand than that of the Nile as well as fine mud. On the latter river it would probably not be easy to make similar observations, as its bed both above and below the Barrage was, he supposed, nearly all covered with water even in the driest season. It was, of course, necessary to the stability of weirs across rivers, with beds of fine material to very great depths, that the surfaces of such beds should be kept as clear as possible of shoals and islands in the vicinity of the work. In a neglected river of this kind, islands were apt to be formed, dividing the main stream into two or more parts. These streams rejoining a little above the work produced cross currents scouring out the bed, undermining solid masonry, and sinking boulders beneath the fine material. Where a proper department was maintained, none of these evils need be feared. The training of rivers was an interesting work, and, if kept steadily up, by no means difficult in any country provided with a government both willing and free to provide the necessary funds.

*** The Author, being in Egypt, has not yet had an opportunity of replying to the correspondence.

SECT. II.—OTHER SELECTED PAPERS.

(*Paper No. 2082.*)

"Harbour Works in Algoa Bay, Cape Colony."

By WILLIAM SHIELD, M. Inst. C.E.

ALGOA BAY, on the south coast of Africa, is the principal harbour of the eastern province of the Cape Colony, possessing a partially sheltered anchorage and good holding-ground. The harbour works which have been carried out there, from time to time, for improving the access to Port Elizabeth, which is situated in a bight formed by Cape Recife, at the western side of the bay, furnish an example of failure and remedial works on a sandy coast.

Port Elizabeth is the principal commercial port of the Cape Colony, its exports and imports being nearly equal to those of all the other ports taken together, including Cape Town. The values of its exports and imports for the thirteen years ending with 1882 were £35,201,718 and £33,349,661 respectively, as compared with £42,539,259 and £14,585,164, for all the other ports; and the tonnage of the vessels entering and leaving the port increased from 86,784 tons and 83,617 tons respectively, in 1864, to 825,157 tons and 838,241 tons in 1882.

Cape Recife extends about 6 miles to the southward of Port Elizabeth; and Point Padrone, forming the eastern extremity of the bay, lays about 43 miles to the eastward. The port is sheltered by land from S.S.E. round by W. to N.E. It is exposed between N.E. and E. by S. to a fetch varying from 10 to 43 miles; and from E. by S. to S.S.E. it is open to the Indian Ocean. The port is also exposed to very heavy rollers raised by south-west winds, which wheel round Cape Recife, and prove more trying to sea-works than waves produced by south-east gales. Westerly winds occur throughout the year; gales from the north-west are most common during the winter; and east to south-east winds are prevalent during the summer, from September to March. Westerly gales are generally the most violent; but very heavy gales occasionally blow from the south-east. The heaviest rollers approach-

ing Port Elizabeth come from east (magnetic) to 20° south of east, and cause an almost constant surf upon the beach, making landing somewhat difficult. The highest waves observed by the Author were about 20 feet from trough to crest, in a depth of about 23 feet.

Currents.—Numerous current observations were made by the Author, with floats offering very little surface to the wind, and so adjusted generally as to indicate the current at a depth of 7 feet; and the direction and force of the wind were noted during the experiments. These observations, extending over about eight years, proved:—(1) That there are no appreciable tidal or other defined currents in the vicinity of Port Elizabeth. (2) That such currents as occasionally exist, with the exception of the shore-currents, are surface currents produced by the wind, which change their direction and velocity with the wind. (3) That the shore-currents are due entirely to wave-action, and extend seawards in proportion to the height of the waves. (4) That in consequence of the exposure of the bay to south-east winds, and also owing to the direction of the rollers, the set along the coast is very frequently from south to north, especially in the season of south-east winds; but during the prevalence of north-westerly, northerly, or north-easterly winds in the winter, the set is in the opposite direction; and with westerly winds, and in calm weather, there is often no current at all.

Sand-Travel.—The travel of sand along the shore is frequently from south to north. With westerly winds, however, sand accumulates upon the beach, and still more with northerly and north-easterly winds, as they check the tendency of the waves to pass the sand on. This movement of sand does not extend beyond the action of the waves, and it is most readily checked by any impediment to its progress.

Tides.—The datum line at Port Elizabeth is the average low-water of spring-tides; but good spring-tides frequently fall 15 inches lower, and have a range of 7 feet; whilst exceptional tides fall 18 inches below it, and rise 8 feet. The ordinary range of neap-tides is from 2 to 2½ feet; but sometimes the variation in water-level is less than 12 inches.

The Agulhas current, outside the bay, appears to exercise a considerable influence on the tides, for when accelerated by easterly or south-easterly winds, it draws the water out of the bay, increasing the fall, and diminishing the rise of the tide; and when retarded by westerly or south-westerly winds, it has the reverse effect. The wave-disturbance produced by the volcanic

eruption in the Straits of Sunda (distant about 5,000 miles), on the 27th of August, 1883, reached Algoa Bay between 4 P.M. and 5 P.M. that day; three distinct waves, which appeared between 7.55 and 10.15 P.M., swung the ships anchored in the bay almost broadside on to their cables; and the undulations recorded by the self-registering tide-gauge at Port Elizabeth showed a series of rapid rises and falls, with a maximum variation of water-level of 5 feet 4½ inches between 8.19 and 9.2 P.M., which did not entirely disappear from the tidal diagrams till about five days after.

Breakwater.—The want of shelter at Port Elizabeth from the south-east led to the construction of a breakwater, which was commenced in 1856 (Plate 3, Fig. 1). This breakwater had a total length of about 1,700 feet, and consisted of a straight arm, 46 feet wide, projecting out from the shore, with a return outer arm, or shield, 63 feet wide. The deck level was 8 feet above high-water. The first 330 feet from high-water mark, composed of stone walls with rubble filling between, was completed in August 1857. The remainder of the breakwater was formed of pilework, with a rubble wall on the exposed side, and rubble filling on the harbour side (Plate 3, Figs. 2, 3 and 4). The pilework was commenced in June 1858, and had been extended 740 feet in September 1860, into a depth of 17 feet at low-water. In February 1861, Mr. Warren, the Resident Engineer, reported the formation of a sandbank 3½ feet high, on the north side, at the outer end of the work. The filling-in with rubble was commenced in November 1861, at the seaward end; 21,021 tons, out of 26,000 tons required to fill the breakwater up solid to low-water level, had been deposited by the end of July 1862; and the pilework of the shield was commenced in April 1862. The straight breakwater was accordingly becoming a nearly solid structure, almost before the commencement of the shield. In September 1862, Mr. A. T. Andrews, M. Inst. C.E. (then Resident Engineer at the Table Bay Harbour Works), advised that no more stone should be deposited, as he considered that sand would collect in the still water under shelter of the breakwater, and form a dangerous shoal, but that the shield might be filled up with rubble as designed. In April 1863, Mr. Bourne (then Colonial Railway Engineer) recommended that the breakwater, as well as the shield, should be filled up with rubble as soon as possible to quay-level, leaving only a length of 300 or 400 feet of pilework next the stone approach, at the shore end, to be filled up eventually if experience proved that no injury from silting was liable to result.

Silting in Harbour.—The Harbour Board followed Mr. Bourne's advice, so far as regards the outer portion of the work; but instead of stopping the stone filling as soon as sand began to accumulate in the harbour, carried it on as rapidly as possible to the shore, in the hope of preventing the drifting sand, which followed up the filling, from coming in through the opening. The closing of the breakwater was completed in July 1865; but serious silting-up still continued on the north side, and by November the deposit in the harbour formed a junction with the advancing beach. Though the portion of the harbour used by vessels of 400 to 500 tons had been little affected by the accumulation of silt up to February 1866, the beach continued to advance both north and south of the breakwater. In October 1867, the low-water mark had advanced 750 feet; in December 1868, it was within 200 feet of the shield; and by June 1869 it had extended beyond the sea-face of the shield, completing the destruction of the harbour (Plate 3, Fig. 1). A bank also had formed to the north-west of the shield, which, in 1869, rose to within 3 feet of low-water spring-tides, and presented a serious obstruction to landing on the beach.

Schemes of Improvement.—Sir John Coode, Vice-President Inst. C.E., was consulted for the first time in 1868; and he arranged for Mr. Charles Neate, M. Inst. C.E., to inspect the site. Mr. Neate, during his visit, recommended that an opening should be made at the east end of the straight breakwater, to arrest the rapid advance of the sand, and the construction of a jetty with the timber taken from the breakwater; and this work, having been approved by Sir John Coode, was carried out for a time under the direction of Mr. A. T. Andrews. In 1870, Sir John Coode recommended the following works:—(1) The opening out of the straight breakwater; by removing all the rubble for a length of 500 feet, and drawing such of the piles as were not required for supporting a viaduct; (2) The construction of a retaining bank, 1,600 feet long, to the south of the breakwater; (3) The formation of an outer harbour by an extension of the shield, and an inner jetty 400 feet long; (4) Inner works, comprising an entrance basin, and an inner basin of 14 acres in the valley of the Baakens river. In consequence, however, of the complex conditions of the case, he recommended that these works should be carried out in sections, so that experience might indicate how far the desired results were or were not likely to accrue from their construction.

The opening out of the breakwater was commenced in 1869, and

proved a very tedious and difficult operation. In 1875, instructions were given by the Harbour Board for carrying out the retaining bank and the outer jetty forming the first section of the above scheme, and the Author was appointed Resident Engineer for these works in 1876. After a personal inspection of the port in December 1876, and owing to the enormous sand-travel and absence of any constant currents revealed by the investigations of the Author, Sir John Coode recommended that a breakwater pier, nearly parallel to the shore, should be constructed at a distance out of about 3,000 feet, with return ends to keep off the swell, and provided with a fully-equipped quay, and with jetties projecting from it in a westerly direction, alongside which vessels of the largest class could discharge and load. The breakwater was to be connected with the shore by an open iron viaduct carrying two lines of railway. The in-shore works comprised the construction of a retaining-wall, 2,100 feet long, and the raising of the land thus reclaimed; the removal of the old breakwater to a depth of 3 feet below low-water spring-tides (afterwards carried to 5 feet over the shield, and 7 feet over the remainder); the extension of the jetty 200 feet; and the construction of a bridge for two lines of railway across the Baakens river. The inner works were designed to afford speedy relief to the port, by removing the sandbanks which had been formed, and setting back the line of the beach as near as requisite to its original position. Before embarking upon these large works, the Cape Government arranged that Sir John Hawkshaw and Mr. (now Sir James) Brunlees, Past-Presidents Inst. C.E., should confer with Sir John Coode; and they reported their approval of the scheme in July 1880. As the general local opinion was strongly in favour of having a dock for the port, Sir John Coode modified his design as shown on Plate 3, Fig. 7, providing a dock with jetties under shelter of the breakwater. The estimated cost of the work is £1,170,950; but, up to the present time, the in-shore works alone have been executed.

Retaining-Bank or Sea-Wall.—The line of the retaining-bank (Plate 3, Fig. 7) was designed with the view of causing the waves, which impinge upon it at an angle of between 60° and 80°, to scour away the sand-spit formed by the old breakwater, and to clear off the sand from the rubble filling of the breakwater, so as to admit of its removal by divers. A bank *a* (Plate 3, Fig. 5), composed chiefly of large stone and concrete block varying in weight up to 7 tons, was first carried forward at a level of 10½ feet above low-water spring-tides, and was followed up by a second bank, *b*, on the land side, which was always kept a little back from

the end of the outer bank for the sake of shelter. The material was mostly tipped from wagons running on rails along the top of the banks; but some of the larger stones and blocks were placed by a crane. The lines of way were frequently displaced by the sea; but the expenditure on their maintenance was much less than staging would have cost. Seas washing over the bank made the rubble settle down, and formed a long slope on the inside of well-washed quarry chippings and grit, so admirably suited for concrete that the slope was kept fed with fine quarry materials for the purpose. The material for concrete, thus collected, generally contained sufficient grit to enable sand to be dispensed with.

When the mound was sufficiently consolidated, a trench was excavated along the top, in short lengths, within which blocks were formed in position, in timber boxes lined with jute sacking. These blocks form a lower wall, or apron, 4 feet wide and from 7½ to 8 feet deep (Plate 3, Fig. 6). Blocks of 40 and 20 tons were laid alternately; and the concrete of the 20-ton closing blocks filled up the grooves left in the ends of the 40-ton blocks, thus making the wall a continuous mass. Large stones, clean and well-bedded, were incorporated in all large masses of concrete, for the sake of economy. Levels taken for a considerable period on the top of the apron failed to indicate any appreciable settlement. Two gangs, of eight Kafirs each, mixed and deposited 41 cubic yards of concrete per day when the moulds and stages were fixed for them.

After the completion of the apron, the rubble behind it was left to consolidate as long as possible before the crest wall was commenced. This wall was founded in the rubble, 2 feet below the surface of the apron, and was constructed in sections, 8 feet long, with chamfered joints on the sea face. Each section or block, weighing nearly 18 tons, is keyed to the adjoining ones by vertical dowels, so placed that any block is free to settle without disturbing the work; but though the work was completed more than five years ago, and has been assailed by heavy seas, no settlement is visible. The concreting was effected by two gangs of thirteen Kafirs each; and each gang mixed and deposited about 31½ cubic yards of concrete per day.

After the completion of the crest-wall, it was backed up with rubble; and a line of rails was laid, on which a 7-ton steam-crane travelled, which fed and trimmed the bank with large stone and concrete blocks. The bank eventually assumed a slope of about 4 to 1, at which it has stood for a considerable time.

The cost of the concrete in the apron was £1 9*s.* 10*d.*, and in the

crest wall £1 3*s.* 1¼*d.* per cubic yard. The greater cost of the lower wall was due to its being tide-work, and requiring extra precautions against the sea during construction. The total cost of the retaining bank, including the raising of the 16¾ acres of reclaimed land, amounted to £64,514; and its construction occupied about three and a half years, having been commenced in May 1877, and carried on, under the Author's supervision, simultaneously with the removal of the breakwater.

Removal of the old Breakwater.—The removal of the breakwater was commenced in September 1869; and by March 1871 a partial opening, extending 138 feet inland from the shield, had been made. In 1876, the rubble and piles had been partially removed along a length of 500 feet altogether, five hundred and eighty-two piles and a large quantity of sheeting having been drawn out by hydraulic presses and levers, and one hundred and sixty-nine piles sawn off under water by divers. The drawing of the piles was very laborious, as they were only roughly squared, and they were held so tight by the angular rubble that the 1¾-inch chain cable attached to them was often broken. The removal, also, of the rubble below low-water, prior to the construction of the retaining bank, was rendered very difficult by the deposit of sand, which could be only partially arrested by screens of sheet-piling with canvas, and dams of sand-bags.

As many of the stones in the shield weighed from 6 to 7 tons, a steam crane was procured capable of lifting them. The iron-wood piles of the breakwater, however, were so much eaten by the teredo that they were quite incapable of carrying this crane which was a heavy machine. Accordingly fresh piles were driven into the rubble alongside the old ones, but could only penetrate about 5 or 6 feet into the mound. The staging thus formed was therefore not so rigid as could have been wished, so a short length of it was specially braced and strengthened, and the crane was lashed on it, when not at work, in preference to bringing it back along the whole length of the breakwater, till its work on the shield was completed. The rubble along the remaining portion of the breakwater, being smaller, was removed by hand-cranes. The rubble was only removed down to 5 feet below low-water spring-tides in the shield, and 7 feet in the straight breakwater, as at this depth it forms a reef, on which heavy seas break, and in a measure protects the landing beach.

The piles were subsequently broken off by a 19-oz. dynamite cartridge, placed in a 2-inch hole bored in the pile at the level of the lowered rubble, and fired by electricity. Double-headed 80 lb.

rails, which tied many of the piles together, being attached to them by 1¼-inch bolts, were detached by two dynamite cartridges, weighing together 4·8 ozs.

The removal of the rubble was liable to be stopped by the accumulation of sand during fine weather and off-shore winds; whereas rough weather, which stopped the diving work, drove the sand away. The best time for work was after rough weather from the south-east, or after a strong westerly swell. As much of the rubble as possible was removed from the shield under shelter of the parapet, which was then taken away in short lengths as the stones supported the timberwork, and it in turn kept together the stones. The stone was removed first; and the timberwork was then cut away as quickly as possible, as it was liable to break adrift and injure the staging. When the shield had been sufficiently lowered for the sea to wash over it, the waves heaped up the rubble against the landward row of piles, and formed a bank, about 70 feet wide, on the landward side of the structure. This inner row of piles was left to the last, to hinder the rubble being driven in-shore; and the removal of the rubble, thus arrested, was facilitated by a considerable portion of it being raised by the waves above low-water. The bank of rubble, landwards of the shield, was mostly removed by small bags and spoons, guided by divers.

The total cost of removing the breakwater was £38,500, or about £26 18*s.* 6*d.* per lineal foot removed, including 350 feet landwards of the retaining wall. Its construction cost £122,438.

The success which has attended the remedial works is indicated by a comparison of the state of the port in 1876 and in 1884 (Plate 3, Figs. 1 and 7), from which it will be seen that there are now 2 fathoms of water at low water, where previously to the operations above described there was a bank of sand dry at low tide.

Bridge over Baakens River and other Works.—A bridge carrying two lines of railway connects the works south of the Baaken-River with the Midland system of railways. It crosses the river obliquely, with three spans of 30 feet, and rests upon cylindrical columns, 2½ feet in diameter, founded upon concrete bases, and concrete abutments. Corrugated sheet-iron, No. 24 B. W. G. in thickness, formed the dams for the piers and south abutment, being stayed inside with timber framing, and weighted with rails so that the dam sank into the sand and gravel as the excavation proceeded inside. The dams for the piers were about 42 feet long, 6 feet wide, and 8 feet high; and they were perfectly watertight.

The Author thinks that this, as he believes, novel use of corrugated iron will be found satisfactory and economical where, as in the present instance, clay is expensive and difficult to obtain of good quality. The bridge, with its approaches, cost £4,947.

The other principal works recently executed at Port Elizabeth, under the Author's supervision, comprised the removal of a timber jetty, 465 feet long and 60 feet wide, and the construction of two wrought-iron jetties, 900 and 840 feet long respectively, at a cost of about £118,000, including equipment with steam-cranes, &c. (Plate 3, Fig. 7), for facilitating the work of the port, which previously had been almost entirely conducted on the beach by means of surf-boats.

The communication is accompanied by six sheets of illustrations, from which Plate 3 has been compiled.

(*Paper No. 2135.*)

"Friction-Clutches."

By Walter Bagshaw.

The passing of the Employers' Liability Act, and the rapid progress of electric-lighting, did much to stimulate a demand for improved methods of connecting or disconnecting machinery and its motive power whilst in motion, primarily with a view to avert the risk of accident; but on the grounds of convenience and economy alone, the merits of well-designed arrangements soon found recognition.

Friction-clutches, however, may be employed under all circumstances, and in contributing this brief outline to the present scanty literature on the subject, it has been the aim of the Author to give typical examples of successful application to dredging-vessels, electric installations, tram-cars, turbines, pile-drivers, or other machinery likely to come within the province of a civil engineer, which may be afterwards modified to meet almost any requirements of daily practice.

The principles observed in designing friction-clutches are founded on the ordinary laws of friction of solids, the coefficient 0·10, friction of quiescence, cast-iron on cast-iron with plain greasy surfaces being found to yield satisfactory results where there is little fluctuation of energy. In such cases the sizes of clutches are computed according to the HP. to be transmitted and the number of revolutions per minute, allowing a considerable margin for the inertia of the resisting medium whenever the clutch is put into action. But where the character of the strains is intermittent, violent, or irregular, the dimensions are regulated by the nature of the work, and have been determined by experiment for a variety of purposes.

In journals with lubricated surfaces there is a considerable variation in the friction under changes of temperature, the coefficient of friction at 120° Fahrenheit being only one-third of what it is at 60°, when lard oil is used;[1] and in practice it is found

[1] Institution of Mechanical Engineers. Proceedings. 1883. Report on Friction Experiments.

that a greater pressure is needed to keep the friction-surfaces of clutches with lubricated faces in proper connection under high temperatures than under low temperatures.

With dry surfaces, however, there is no reason to believe that much variation of friction occurs. Clutches, that have been neglected and allowed to get very hot when out of gear, transmit about the same power when put into gear as when they are cold. The following experiments were made to ascertain the difference in the angle of repose at temperatures up to 620° Fahrenheit.

Materials.	Temperature.	Surfaces.	Angle of Repose.
Cast-iron on cast-iron.	Both at 50° F. . .	Plane surfaces dry and polished.	10°
	One piece at 50° F. on one at 212° F. . .		9½°
	One piece at 50° F. on one at 620° F. . .		10½°
	Both at 620° F. . .		11°

Thus with a difference of 570° in the temperature between the first and the last two experiments, there is only a difference of 1° in the angle of repose.

Efficient systematic lubrication doubtless exercises considerable influence on wear and tear, whilst, again, the form of friction surfaces affects the constancy of lubrication. Some clutches have been continuously at work for years without appreciable wear, though the velocity of the rubbing-surfaces in some instances exceeded 3,000 feet per minute, and the pressure per square inch was 500 lbs. at the moment of approach. Flat surfaces are better than curved or serrated surfaces. When the friction between the surfaces is sufficient to overcome the resistances, the only limit to the pressure that may be applied is the strength of the materials, because the rubbing-surfaces are relatively at rest. This pressure may be adjusted so that any increase of resistance shall cause the clutch to slip. Where power is sublet to several tenants, such an arrangement would prevent loss to the proprietor, and would make tenants careful not to overload their machinery.

Clutches may be divided into: Those capable of transmitting motion in either direction; and those capable of transmitting motion in one direction. And again into: Those in which the pressure applied to the friction-surfaces has to be maintained; and

those in which pressure on the friction-surfaces remains constant, without external assistance, after the external surfaces have been put in contact.

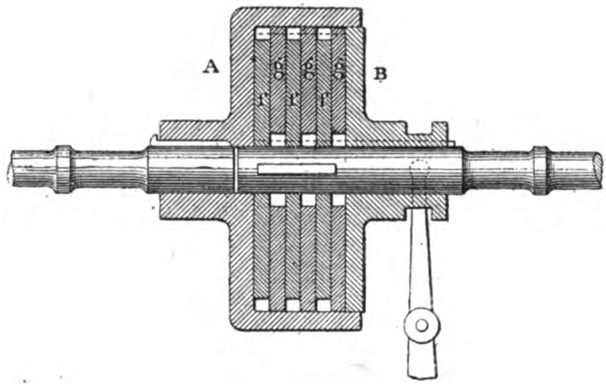
The cone-clutch is one of the most primitive, and at the same time most convenient, methods for the transmission of small powers. The male part slides on a feather-key lengthwise, and the female part may be either keyed on the continuing shaft or may run loose on the same shaft against a fast-collar as a pulley or wheel. The taper of the conical surfaces depends upon the materials of which they are made, and must be great enough to prevent jamming. Frequently one face is iron, whilst the corresponding face is lined with wood, leather, copper, or paper. The main objection to clutches constructed on this principle is that the manipulating lever has not only to put the friction-surfaces into contact, but to hold them there, the result of which is a tendency to work out of gear, and a loss of power through friction on the shipping arrangement and journals produced by end-pressure.

The disk or plate-clutch may consist of two or more disks. A very useful and common form is that applied to dye-vats, for alternately winding cloth through the liquid in one direction or the other. The two driving-disks, which are rigidly connected to the same boss or sleeve, are moved endwise on the shaft, so as to put either of them into contact with the plate, which is secured by a set-screw or key on a shaft at right-angles to the driver. Besides the facility with which the direction of motion may be reversed, a further advantage obtained with this arrangement is the variable speed of the driven-shaft with a constant speed of driver. By moving the driven-disk to or from the centre of the driving-shaft a slower or quicker speed will be given.

Weston's clutch or brake, Fig. 1 (p. 371), consists of a series of flat disks capable of being moved to a small extent longitudinally, and made to turn along with the shaft by means of grooves and feather-keys. Between each pair of the first set of disks $f\,f\,f$ is placed a disk g, belonging to a second set, fitting and turning with the shell A. The disks $f\,f\,f$ turn with the part B. When end-pressure is exerted, all the disks in the second set are gripped by the first set, and the two sets revolve together. It is a peculiar feature of this clutch that, with the same load, the frictional effect may be multiplied by increasing the number of disks in the two series. One of these clutches has been working in Paris on a guillotine, to catch twenty times per minute, at the bottom of a 3-foot drop, a blade weighing 5 tons. Clutches up to 1,000 HP. have also been applied

to rail-rolling mills, when the pressure on the disks has been applied by hydraulic power.

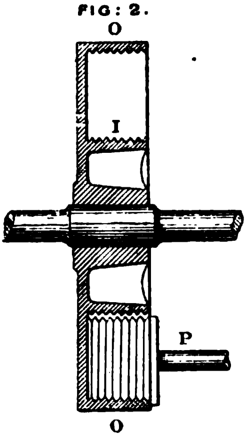
FIG: 1.



WESTON'S CLUTCH.

Robertson's grooved surface-clutch, Fig. 2, greatly reduces the pressure upon the bearings consequent upon plane surfaces. The grooves vary in pitch from $\frac{1}{8}$-inch, for light work, to $\frac{3}{4}$-inch for heavy work, and are formed at an angle of 50°, the ridges of one surface entering the grooves of the other. There is a gain in the effective driving-power of 50 per cent. of the pressure applied to keep the grooved faces in contact. The slip occasioned by the difference of diameters of the points of the ridges and the bottom of the grooves is imperceptible in practice, and there is little wear when the surfaces are large enough to prevent abrasion. Several applications of this clutch have been described.[1] The one shown is a simple arrangement for reversing or for changing the speed. A quick speed may be obtained by putting the pulley P into gear with the outer rim O, and a lower speed in reverse direction by putting it into gear with the inner rim I.

FIG: 2.

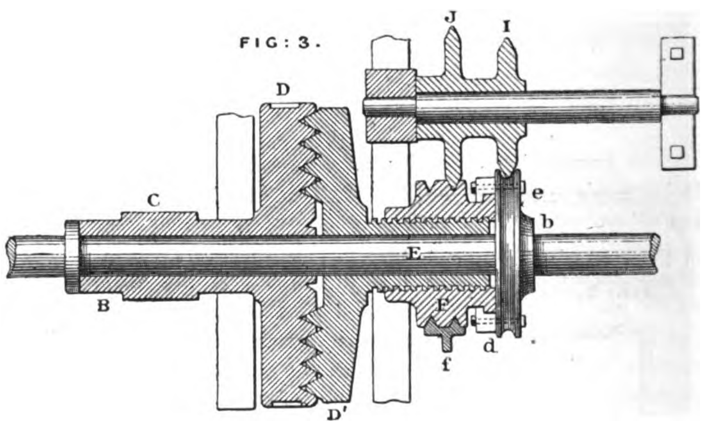


ROBERTSON'S CLUTCH.

[1] Institution of Mechanical Engineers. Proceedings. 1858, p. 202.

Presbrey's clutch, Fig. 3, is a form of Robertson's clutch with appliances for locking the disks together without putting end-pressure upon the bearings of the shaft. B is a hollow shaft carrying a pinion, or pulley C and a disk D coinciding with the face of disk D′, carried by a sleeve E. The sleeve E is threaded externally to receive a nut F, which takes its end-bearing against a fast collar *b*, and is provided with a flange *e*, which is overlapped by a flange ring *d* bolted to the collar *b*, and serving to connect the nut to the collar without interfering with the free rotation of the nut. By imparting to the nut a rotation at greater or less speed than that of the shaft carrying it, the nut is caused to turn upon the sleeve E, thereby carrying the latter and its disk by a powerful

FIG: 3.



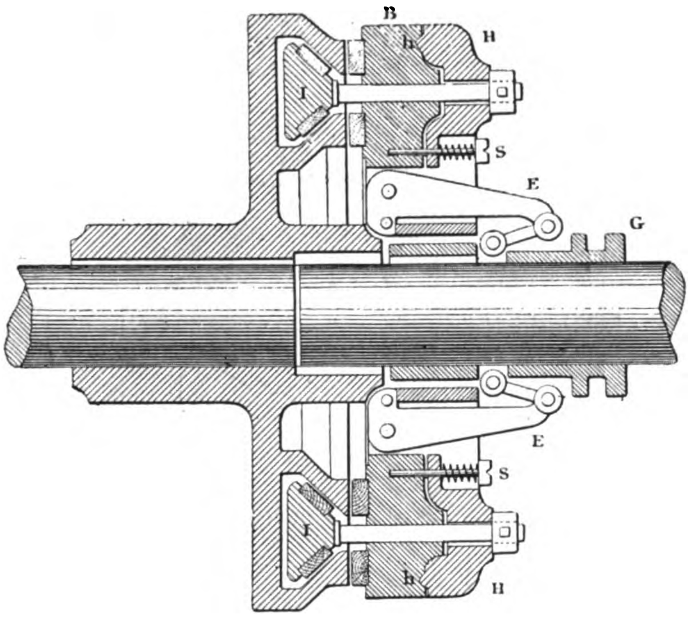
PRESBREY'S CLUTCH.

pressure towards or from the opposite disk D. By proportioning the friction-disk J larger in diameter than the disk I, the nut may be made to travel faster than the shaft, whilst the motion of the nut may be retarded on application of a brake *f*.

Frisbie's clutch, Fig. 4, is an ingenious combination with toggle-levers. The parts A and B are keyed fast upon their respective shafts, the levers E E having their fulcrums in wheel B, and their opposite ends attached by links to a sliding-piece G, which when moved, operates on the levers H H, turning them slightly on the knife-edges *hh*. Bolts from the levers H H are connected to dovetail pieces, I I, faced with lignum vitæ, and put them in contact with the conical faces of the recess. Springs S S take up the lost motion of the parts.

Simons' clutch is a German invention, and consists of a modification of the so-called umbrella-clutch, in which the contact-surfaces are cylindrical and grooved, as in Robertson's arrangement, while the friction-blocks are connected to the sliding-sleeve by curved springs instead of by rigid arms, whereby the blocks may be brought into contact with the flange of the disk with an increasing elastic force. The pivots by which the arms are attached to the sleeve may be carried beyond the vertical line drawn through pivots at the other end of the arms, so that there shall

FIG: 4.

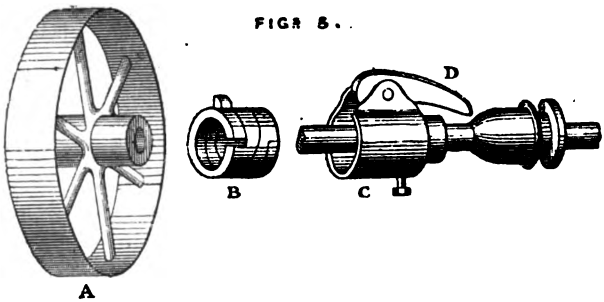


FRISBIE'S CLUTCH.

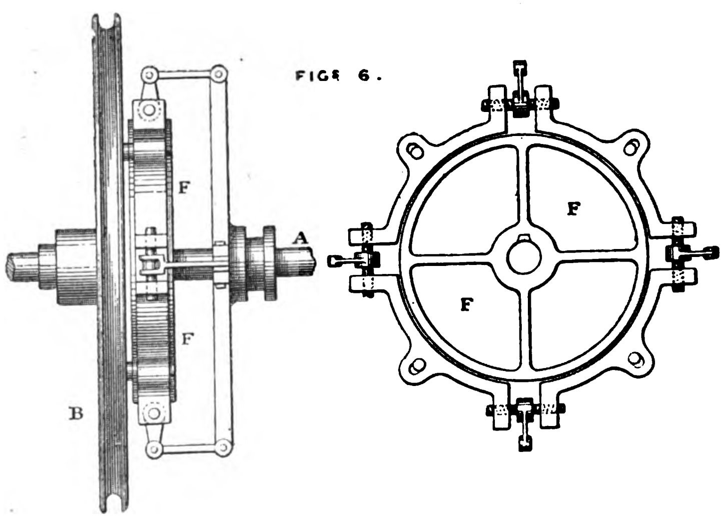
be no tendency for the sleeve to move backwards after it is once put into gear.

In Rider's clutch, Figs. 5, a spiral spring B is bored to fit a projecting boss on the pulley A, and both boss and pulley are encased by a shell C having a slot through which a projection on the spring passes. The taper end of a lever D engages with this, and on movement of the sliding-piece E, tightens the grip of the spring, the opposite end of which is secured to the shell by a set-screw on the pulley boss, with a theoretical frictional effect equivalent to the number of coils raised to its own power.

Fisher's clutch, Figs. 6, has a disk-plate fixed to the wheel B and free to rotate on the shaft, or to remain stationary when out of gear. F is a wheel keyed fast on the shaft A, and clasped by four belts, centred on and carried by the disk-plate, connected at the ends by right- and left-hand screws, whereby the belts may



RIDER'S CLUTCH.



FISHER'S CLUTCH.

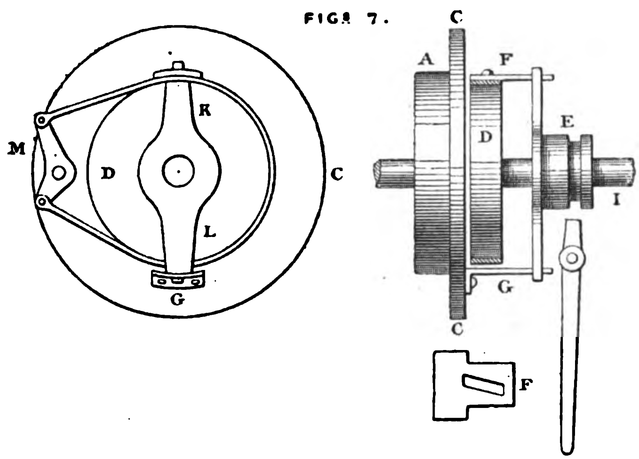
be closed or expanded. When closed upon the wheel F, the whole is locked together and revolves with the shaft.

The Bates clutch is a simple form of Rider's clutch. The hub of the pulley or wheel is surrounded by an annular spring severed transversely, the ring being such that after it has been contracted, it returns to its original size by elasticity.

The ring is contained within a casing, keyed to a shaft, in which casing is an opening for a wedge. By the insertion of this wedge the opposite ends of the spring are drawn together and carry the wheel round with it.

Figs. 7 represent Napier's differential-clutch. C is a disk forming part of the wheel A, and it carries the fulcrum of the differential-lever M, to the ends of which a brake-band is fixed. This band encircles a pulley D which is fast upon the shaft I. E is a boss which can both slide and turn upon the axis I; it has two arms K and L, the extremities of which pass through slotted plates, F and G. One plate is fixed on the brake-band. The other plate is similar, but is fixed on the disk C; thus, by moving

FIGS. 7.



NAPIER'S CLUTCH.

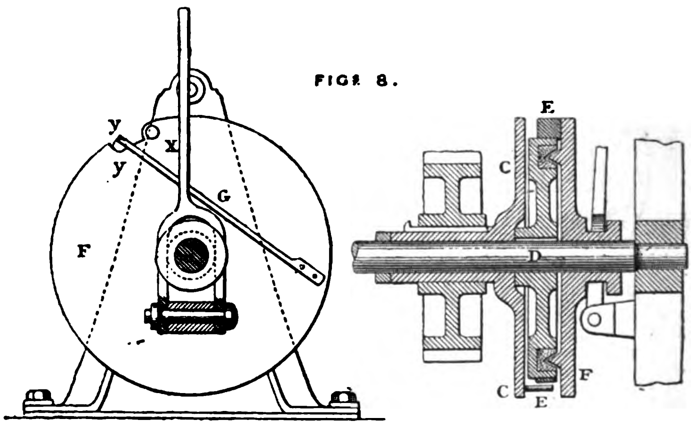
the boss E along the shaft, the lever M can be caused to rock on its fulcrum, and the brake-band can be tightened or slackened.

A good example of clutch, which acts in only one direction, is that applied to the vertical Otto gas-engine for the purpose of making a connection between the shaft and piston during the down-stroke. The wheel driven from the piston is made with inclined internal surfaces, against which sets of rollers travel, and press upon curved wedges, while the piston is descending. The opposite sides of the wedges are faced with leather and grip the driven-pulley. In the up-stroke no pressure is brought upon the wedges, and the wheel is free to revolve upon the shaft.

In Weston's clutch, Figs. 8, friction is set up or induced by the action of one pair of surfaces upon another or several other

pairs, their combined forces being exerted on the resisting load. On the shaft B is placed a loose disk C, next to which is keyed upon the shaft a brake-pulley D, having its side furthest from the disk made with an annular V groove for the corresponding projecting face of an adjacent loose disk F, capable of sliding laterally and rotating freely upon the shaft: a flexible brake-strap E extends from a pin X in the loose disk F, and passing round the pulley D terminates at its other end upon a pin *y* fixed in the loose disk C. A spring G is used to quicken the release of the strap. The action is as follows:—When the disk F is pressed laterally, against D, it receives rotary motion and exerts a tensional strain upon the brake-strap, wrapping it tightly around the brake-

FIGS. 8.



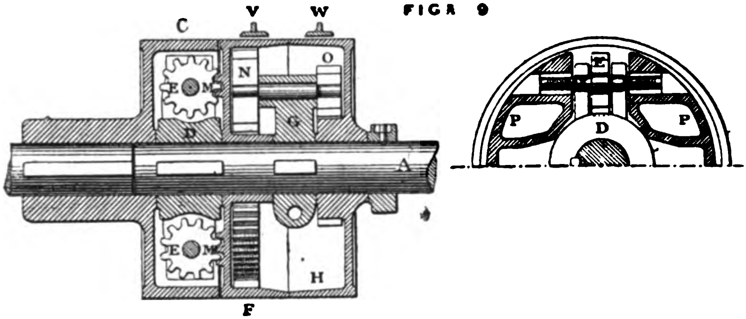
WESTON'S CLUTCH.

pulley under the resistance furnished at the other end of the strap by its attachment to the pin *y*. The pull upon the strap E, due to the action of the first pair of V faces, thus induces frictional action of the strap and pulley, and the combined force is exerted on the resisting load on the wheel keyed upon the disk C. Instead of a single strap, a compound strap, passing twice or three times round the pulley, may be used.

The working of Braun's coupling, Figs. 9 (p. 377), is as follows:—If the coupling is to be put into gear, the casing H is held stationary by the brake-block W. As the lever G is fixed on the shaft A, the casing F will move in advance of the shaft A to the same extent to which the casing H remains behind, as the proportion of the toothed rings (not shown) to their pinions O N is the

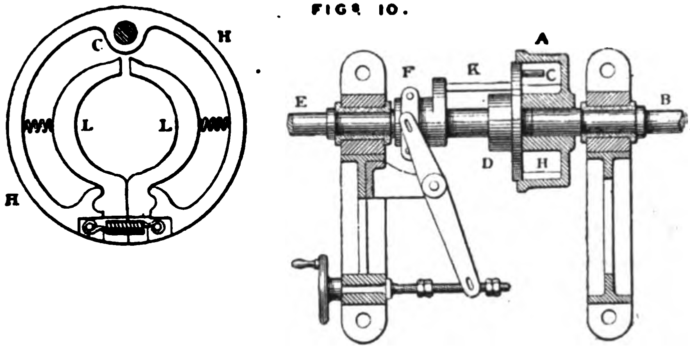
same. As the cross-piece D makes the same number of revolutions as the shaft A, the spiral M will turn the two pinions E E in the direction towards the periphery of the casing, whereby the screws X will be rotated so as to cause the brake-blocks P to be pressed against the casing C. The brake-block W being released, the parts will remain in this position until the part F is held stationary by the application of the brake-block V, when a reverse action will take place causing the shafts to be uncoupled.

FIG. 9



BRAUN'S COUPLING.

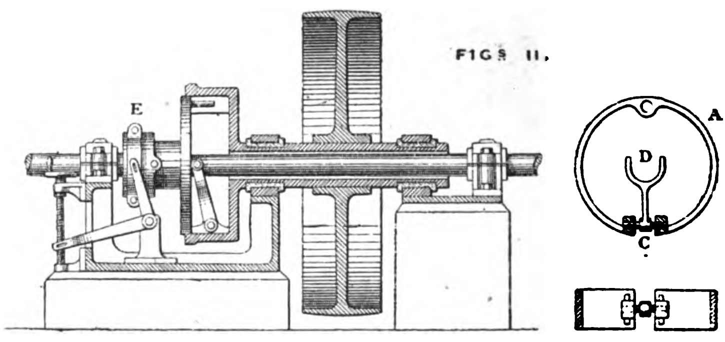
FIG. 10.



ADDYMAN'S CLUTCH.

Figs. 10 represent Addyman's clutch. A is a hollow shell bored out to the same diameter as the friction-ring H, and keyed fast on the driving-shaft B. On the driven-shaft E a disk D is secured, having a crank-pin or driver C, to which is attached the friction-ring H, and on the same shaft the wedge-piece F slides over a feather-key. The taper of the wedge is made to correspond with the angle of repose, whereby it has no

tendency to work out of gear. The end of one shaft projects into the boss of the piece on the continuing shaft. When the wedge K is moved forwards, it opens out the levers L L, and thereby expands the friction-ring H, thus causing it to grip the whole interior surface of the shell A, and to transmit power from one shaft to the other. As the pressure is first applied at right-angles to the movement of approach of the friction-surfaces, all end-thrust is removed, and only a small effort is required to make the connection. A clutch transmitting 100 indicated HP may be thrown in or out of gear with no more power than can be exerted by the finger and thumb during a few seconds. It is immaterial whether the pulley drive the shaft, or the shaft the pulley; nor does change of direction in the motion make any difference. This clutch is working up to 1,000 revolutions per minute, and in some



BAGSHAW'S CLUTCH.

of the Birmingham stamping-machines is brought into use as often as 1,000 times per hour.

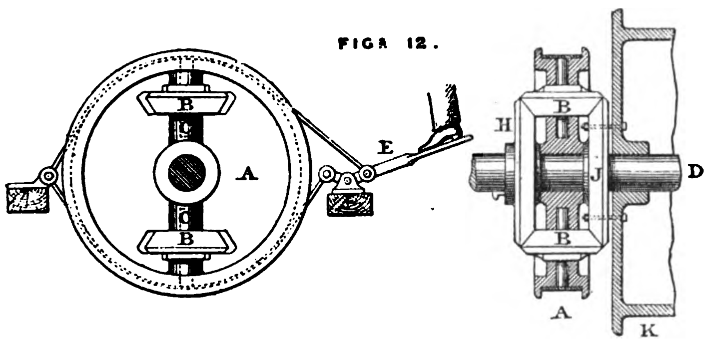
In a clutch devised by the Author, Figs. 11, as a driving-pulley for broad belts, the weight of the pulley and the tension of the belt are taken off the shaft and borne by independent bearings, so that when the clutch is out of gear there is no wear and tear. The ends of the friction-ring A are connected by the right- and left-handed screw C, and to this screw is affixed an arm D, connected with the sliding-piece E by links. By moving this sliding-piece in one direction or the other, the screw is turned, and is caused to either force the ends of the friction-ring apart to expand it, or to pull them together and allow the internal parts to revolve independently of the outward shell and pulley. A direct and firm connection is thus maintained at all times, and there is no liability of

the friction-surfaces putting themselves into action by centrifugal force when not required. A clutch on this principle has been working for three years at Tadcaster flour-mills, during which time it has had the severe duty of coupling a turbine to a steam-engine of 150 HP. In connecting the two at variable speeds no backlash nor other detrimental effect has been experienced; but rather a steady, smooth action free from biting or jerk, whilst slipping or breakage of belts has been entirely prevented.

Wrigley's friction-coupling consists of two segmental friction-blocks, connected by toggle-joints which put them into contact with the internal face of a shell. Adjusting screws take up the wear as required.

Figs. 12 represent Davison's brake-clutch. The disk A is formed with openings in which bevel-wheels B turn freely on spindles

FIGS 12.



DAVISON'S CLUTCH.

C, and both disk and wheels are free to revolve on the driving-shaft D. A brake-strap E clasps the outside rim and is fixed to timber framework. The bevel-wheels B gear on one side with a bevel-wheel H keyed on the driving-shaft, and on the opposite side with the bevel-wheel J bolted to a loose pulley or winding drum K, or on a line of shafting to be driven. By tightening the brake-strap the disk is held stationary, and the pinions B transmit motion from the wheel H on the driving-shaft to the wheel J on the pulley K, at the same speed as the motor-shaft, but in a contrary direction. When the brake-strap is released it is evident that the wheels B will simply roll round the wheel J without transmitting motion.

Probably no single clutch is capable under all circumstances of fulfilling such essential conditions as the following:—Positive reliance at all speeds and under severe and sudden strains; ease

in throwing in or out of gear whilst in motion, and freedom from shocks; non-liability to wear or derangement; no tendency to work out of gear; and last, but not least, moderate price. In all cases experience must guide the engineer in his selection.

Some time ago in Germany a law was proposed, to make it compulsory that the main shaft in every separate room should be arranged for disconnection from the motive power in case of accident; but prudential reasons prevailed over the humanitarian, and the law did not pass. It is beyond doubt, however, that in multitudes of instances if friction-clutches were applied to the various departments of a workshop, or to separate machines, it would result in a saving of time, power, wear and tear, and oil, and would prevent accidents.

The Paper is accompanied by tracings, from which the Figs. in the text have been prepared.

(*Paper No. 2,144.*)

"Iron and Brass Foundries, Point St. Charles Works, Grand Trunk Railway of Canada."

By Frederic Lumb Wanklyn, Assoc. M. Inst. C.E.

(Abstract.)

These foundries were specially designed to meet the requirements of two-thirds of the Company's entire system, and to supply castings to all departments, and not solely to the locomotive and wagon works.

The annual capacity of the iron foundry is 3,000 tons of castings, that of the brass foundry 200 tons. The main body of the foundry is cruciform, 200 feet from north to south, and 200 feet from east to west, with a span of 60 feet and height of 18 feet from the level of the floor to the top of the walls. The building is heated by steam-pipes capable of maintaining a uniform temperature of 54° in the coldest weather. The brass foundry occupies a space of 60 feet by 30 feet in the north end of the building. A line of rails of the standard gauge of 4 feet 8½ inches leads from the main line into the building.

The cupola house is situated in the south-west angle of the main building. Its main dimensions are 31 feet 7½ inches by 20 feet by 20 feet high. There is a light iron stair at one corner for the use of the furnace-men and a hoist for lifting up the charges of fuel and metal. The building is ventilated by annular ventilators passing through the roof round the cupola stacks, similar to those used round the funnels of steam-ships.

There are two cupolas, made of boiler-plate, $\frac{3}{8}$ inch thick, 5 feet in diameter, in five parallel courses, 13 feet 9 inches high to the top of the fifth course; the sixth course is conical, 3 feet 6 inches, contracting from 5 feet in diameter to 3 feet 3 inches at the base of the stack, which is also of boiler-plate, $\frac{1}{16}$ inch thick, built in thirteen parallel courses, 35 feet high, and 3 feet 3 inches in diameter. Each is fitted with a drop bottom. The lining is parallel from the sole-plate to the flare contracting into the stack, of double fire-brick. The course next to the shell, or

outside lining, is of plain fire-bricks, 9 inches by $4\frac{1}{2}$ inches by $2\frac{1}{2}$ inches thick, placed on edge, the small ends down, and backed with about $\frac{3}{4}$ inch of sand to keep them off the rivet-heads in the seams of the shell. The inner lining consists of segmental fire-bricks of a superior quality, 9 inches by $4\frac{1}{2}$ inches by $4\frac{1}{2}$ inches thick, and moulded to a radius of 1 foot $10\frac{5}{8}$ inches, the diameter of the cupola inside the lining being 44 inches. The flare is lined with one course of specially moulded segmental fire-bricks, 9 inches by $3\frac{1}{2}$ inches by $2\frac{1}{2}$ inches thick and 1 foot $8\frac{7}{8}$ inches radius, as is also the stack throughout its entire length with bricks 9 inches by $3\frac{1}{2}$ inches by $2\frac{1}{2}$ inches thick and of 1 foot 4 inches radius, the diameter of the stack inside the lining being 31 inches. The bricks are set in thin fire-clay mortar, consisting of refractory sand and Jersey fire-clay; great care being taken to break the joints of the inner and outer linings, and to make them as thin as possible. A lining, such as the one just described, will last ten months, used daily, before any of the inner lining bricks require renewing. The first to burn out are those in the zone of fusion about 20 inches above the tuyeres. The repairs are carried out without disturbing the rest of the lining; angle-iron rings riveted inside the shell support the lining at three points. The blast is delivered into an annular wind-chest 1 foot 8 inches by 9 inches. Sight-holes are provided in elbows fitted with covers glazed with thick glass and mica or talc, a $\frac{1}{2}$-inch air space being left between the glass and mica, which is on the inside, preventing the glass from being cracked by heat. The tuyeres are five in number, circular, $5\frac{1}{2}$ inches in diameter in one belt, 1 foot $5\frac{1}{2}$ inches from the sole-plate to the centre of the tuyeres, and 3 feet apart. The charging hole is 2 feet 3 inches by 2 feet 8 inches, placed 10 feet 9 inches above the sole-plate. It is fitted with cast-iron doors, which are lined with fire-brick, and carried on a cast-iron frame bolted to the shell. The blast enters the wind-chest at two points directly opposite each other, placed between the tuyeres and not opposite to any one of them. The main blast-pipe leading from the cupola-house to the engine-room is 24 inches in diameter, made of galvanized iron No. 20 B. W. G.; all seams and joints are riveted and soldered to ensure their being air-tight. This pipe is provided with weighted valves opening outwards, which prevent the pressure in it exceeding 16 oz. per square inch.

The blast is supplied by two No. 8 Sturtevant fans. The pressure varies from $8\frac{1}{2}$ to 9 oz. The fans and other machinery are driven by an ordinary high-pressure engine; the cylinder has a bore of 12 inches and length of stroke of 30 inches, indicating

36 HP. The steam for the engine and for heating-purposes is supplied by two boilers of the locomotive type, 11 feet 7 inches in extreme length, and 4 feet 2 inches in diameter. The dimensions of the fire-boxes inside are 5 feet 4 inches by 5 feet 3 inches by 3 feet 9 inches. The main chimney is of $\frac{3}{16}$-inch plate 3 feet in diameter at the base, tapering to 2 feet 6 inches at the top, and it is 62 feet high.

There are two core-ovens, with flues leading into the main boiler-house chimney. They are built of brick, air spaces being provided in the walls to prevent their cracking. The roofs are of iron plate, stiffened with old rails, and covered with a cement mixture of clay and asbestos fibre about 6 inches thick; this is found to keep the heat in well, and does not crack. The general core oven is 18 feet by 8 feet 6 inches by 8 feet high. The other core oven is 20 feet by 10 feet by 8 feet high. The entrance is 10 feet by 8 feet. The door is of iron plate, lifting upward between guides, and balanced. The space above the core ovens is used for storing iron patterns.

There are four cranes in the building, one 8-ton and one 4-ton of 25 feet radius, and one 2-ton and one 1-ton of 20 feet radius. Very light hand-work is moulded on benches. The moulds are made in movable or "snap" flasks, and do not require any flasks round them when being cast, the adhesion of the sand being in itself sufficient to resist the pressure of the molten metal. This method of moulding is very economical; a good bench moulder will turn out forty to fifty moulds per day. The charging hoist in the cupola house is capable of lifting 2 tons, and is run by simple worm and wheel gear with straight and crossed belts, one fast and two loose pulleys. The power to work it is transmitted from the main shafting running through the engine-house by an ordinary tarred $4\frac{1}{2}$-inch hempen rope, running cast-iron V-pulleys 5 feet in diameter; the bottom of the groove in the pulleys is filled with india-rubber. This rope runs outside the building, exposed to all weather, and lasts on an average ten months. The rest of the machinery consists of: a sand-grinding and loam-mixing mill, two rattlers or fettling drums 56 inches long, one of them 48 inches, the other 24 inches, in diameter. The larger of these is mounted on friction rollers, and is built into a wooden chamber lined with sheet iron; the dust coming from the castings being cleaned in the mill is exhausted from this chamber, and blown out of the building. The smaller drum is placed outside the cupola-house, and is used exclusively for separating the iron from the cinders and slag dropped out of the cupolas, which often

amounts to 8 or 10 cwt. One vibratory sand-sifter; one hay-band making machine; a double-wheeled emery-grinder for dressing fins and gates; one small vertical and one small horizontal drill; a machine for breaking pig-iron; this machine enables the furnace-man to break pigs into pieces 8 or 10 inches long; large pieces of pig thrown into the cupola do serious injury to the lining, crushing and bruising the bricks, and they are also apt to scaffold or hang; it therefore pays to break the pigs into small pieces; a drop-weight and pole 30 feet high for breaking up large pieces of scrap, &c. The largest ladles used hold 6 tons of metal; all ladles from 40 cwt. and upwards are geared, and ladles over 1 cwt. capacity are fitted with malleable-iron removable lips.

The brass foundry is divided from the iron foundry by a brick wall 8 feet high, surrounded by an iron railing, 4 feet high. The moulding sand in this department is contained in large troughs over which the moulders work. These troughs are placed along the wall, under the large windows, and down the centre of the shop. The pot-holes or furnaces are placed along the west wall, occupying a space 19 feet 3 inches by 9 feet 3 inches; they are seven in number, six of the ordinary type, 1 foot 6 inches in diameter, and 2 feet 5 inches deep, lined with segmental fire-bricks, 1 foot 7 inches by $4\frac{1}{2}$ inches by $6\frac{1}{8}$ inches thick and 9 inches radius, and are large enough to admit 80-lb. crucibles. The seventh is Fletcher's patent furnace. All furnaces are provided with a forced blast of about 6 oz. pressure, as well as the natural draught from the chimney. The tops of the furnaces are level with the floor; there is an ash-pit in front of the furnaces, 3 feet wide, 4 feet 5 inches deep, covered with a strong wrought-iron grating. The flues all lead into one chimney of $\frac{3}{16}$-inch plate, 3 feet 3 inches at the base, tapering to 2 feet 6 inches at the top, and 40 feet high, lined with fire-brick for about one-third of the way up. The hot gases, before entering the chimney, pass round and heat the core-ovens, which are of iron plate fitted with suitable shelves. At the side of the building opposite the furnaces is a coal bunker, capable of holding 7 tons of coal. The coal is carried from this bunker to the fires in a swing-bucket, travelling on a rail overhead. There is also a double emery wheel and rattler for dressing and cleaning castings. These and the fan are driven by a diagonal engine, having a cylinder 8 inches by 10 inches.

The cost of foundry-materials in Montreal, in 1885, was as follows:—

IRON FOUNDRY MATERIAL.

		£	s.	d.
Scrap iron	per gross ton (2,240 lbs.)	2	6	8
Pig iron, "Langloan," No. 1 . .	" "	4	5	7
" "Summerlee," . . .	" "	4	4	7
" "American,"	" "	4	5	4½
Coke, Reading and Pittsburg Mining Co.,	per net ton (2,000 lbs.)	1	0	10
Coal, Lehigh anthracite lump	per gross ton	1	10	2
" " egg size	"	1	4	2
" Steam, Lower Province Canadian . .	"		15	10
Moulding sand, Canadian	"		4	2½
" " American	"		14	7
River " for core-making	"		5	10
Fire-clay, Scotch, ground, in bags	per 100 lbs.		3	4
" American, in lumps	per net ton	2	1	8
Red clay	per gross ton		7	3½
Fire-brick, Scotch	" 1,000	4	9	7
" American, No. 1	"	27	10	0
" " No. 2	"	11	5	0
Lumber	per 1,000 feet	3	2	6
Flour for core-making	per lb.			1
Sea-coal facing	per net ton	2	13	4
Carbonized lead facing	"	9	7	0
Powdered charcoal	"	10	10	5

BRASS FOUNDRY MATERIAL.

		s.	d.
Scrap brass	per lb.	0	5
Ingot copper	"	0	6
" tin	"	0	10½
Cake zinc.	"	0	1¾
Pig lead	"	0	1½
Antimony	"	0	5½
Crucibles, 60 lbs. capacity	each	8	11½

Cost of Labour.—Foreman, £177 1*s.* 8*d.* per annum; moulders, 10*d.* to 7*d.*; core makers, 8*d.* to 7½*d.*; furnaceman, 7¼*d.*; carpenter, 6¾*d.*; engine-man, 5½*d.*; fitters, 6¼*d.* to 5¼*d.*; labourers, 5½*d.* to 5*d.* per hour; apprentices, per hour, first year, 2*d.*, second year, 2½*d.*, third year, 3*d.*, fourth year, 4*d.*, fifth year, 5*d.* The total cost of production was £7,532 15*s.* 6*d.*, being equal to £6 19*s.* 9*d.* per gross ton, or 0·74*d.* per lb. On further analysis it will be found that 46 per cent. of this amount was paid for labour, 41·3 per cent. for iron, 4·6 per cent. for fuel, and 8·1 per cent. for sundries. The cost of labour may at first sight appear to be high, but it must be borne in mind that a large portion of the castings turned out of a general railway foundry in Canada is light. The proportion of pig iron to scrap used is as one to three. It is expected that the price of castings may be reduced to £6 per ton.

The output of the Brass Foundry from the 1st of January

to the 30th of October, 1885, was 140 tons 15 cwt. 1 qr. 6 lbs., and very nearly represents the full capacity of the foundry, of which the chief part consists of engine and wagon brasses. The cost of production was £8,073 2*s.* 8½*d.*, equal to £57 6*s.* 11*d.* per gross ton, or 6·14*d.* per lb. The labour costs 9 per cent.; metals, 86 per cent.; fuel, 3 per cent.; and sundries, 2 per cent. From this it is evident that whereas the price of labour seriously affects the cost of iron-castings, it makes but little difference in the cost of brass-castings; although the cost per lb. of metal in the latter case, 0·505*d.*, is nearly double that in the former, 0·32*d.*, owing to the work being so much lighter. The cost of brass castings is controlled by the prices of the raw materials; it therefore depends more on the ability displayed in purchasing these than in the smaller economies resulting from the careful management of the brass foundry, whether the company pays dearly for brass castings or obtains them at a moderate price.

General Statement showing the Working of the Iron Foundry from July, 1884, to June, 1885.

	lbs.	Per cent. of metals melted.
Total iron melted	3,066,977	
„ castings produced	2,414,913	78¾
„ mill scrap	300,404	9¾
„ defective castings	54,959	1¾
„ excess after filling moulds	187,737	6¼
„ Waste	108,964	3½

Total amount of fuel used	411,548 lbs.
Ratio of fuel to iron melted	1 to 7½.
Total number of melts	248
„ time in melting charges	263 hours.
Average weight of each melt	9,775 lbs.
Ratio of pig iron to scrap	1 to 3.

General Statement showing the Working of the Brass Foundry from January 1st to October 30th, 1885:—

	lbs.	Per cent. of metals melted.
Total metals melted	358,419	..
„ castings produced	315,342	88
„ excess after filling moulds	18,162	5⅛
„ gates	21,557	6⅛
„ waste	3,358	¾

Total amount of fuel used	433,618 lbs.
Ratio of fuel to metals melted	1¼ to 1.
Ratio of scrap metals to ingot metals	3½ to 1.

The communication is illustrated by a general plan of the works, Plate 4.

(*Paper No. 2,146.*)

"On Utilizing Waste Air in Filter-Pressing; with some results of Pressing Sewage-Sludge at Chiswick."

By Joseph Hetherington.

The pressing-plant at Chiswick Sewage-works consists of two filter-presses, with a chamber capacity of 18 cubic feet each. A steel "monte-jus," or pressing-vessel, of a capacity of 100 cubic feet is attached to each press. The sludge is forced into the presses by compressed air, supplied by a horizontal air-compressor, and stored in a steel air-accumulator of the same dimensions as the monte-jus.

The sludge flows by gravity from the precipitation-tanks into a sludge-tank against the pressing-shed. It is drawn up from there into the monte-jus by the action of an air-pump, and is forced from thence into the presses. After each charge of sludge has been expelled from the vessels, the air which then fills the vessels is blown to waste to allow a fresh charge of sludge to be admitted.

The Author having observed in the working of this plant the great waste of fuel occasioned by blowing the compressed air to waste, has made experiments with the object of utilizing the energy possessed by the waste air. It was one of the conditions under which the experiments were made, that no expense was to be caused to the Local Board. The Author desires to express his thanks to Mr. Ramsden, the Surveyor of Chiswick, for his courtesy in permitting the use of the plant. The pressing-plant is kept in operation sixteen hours daily on four or five days per week, and twelve hours the remaining working days; and as the experiments had not to interfere with the working of the plant, the time available was extremely limited.

An estimate of the energy in the monte-jus, when charged with compressed air at 120 lbs. absolute pressure per square inch, may be formed by considering the case of a cylinder 80 feet long, and 3 feet 6 inches in diameter, fitted with an air-tight piston (Fig. 1). For the first 10 feet of stroke air is admitted at 120 lbs. absolute pressure, and then cut off and allowed to expand behind the piston to atmospheric pressure. This would occur at 70 feet further,

assuming the atmospheric pressure to be 15 lbs. per square inch, and the temperature to remain constant. Calling the amount of energy, x, then

$$80 \div 10 = 8 \quad \text{Hyp. log. of } 8 = 2 \cdot 079 + 1 = 3 \cdot 079.$$

Then $120 \div 8 = 15 \times 3 \cdot 079 = 46 \cdot 185 - 15 = 31 \cdot 185$ lbs. mean pressure.

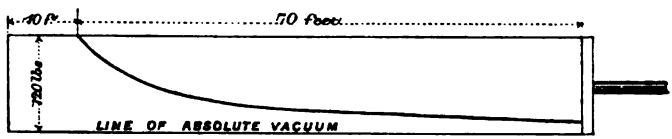
$$\text{Area of piston } 42^2 \times 0 \cdot 7854 = 1385 \cdot 44 \text{ square inches.}$$

$$x = 1385 \cdot 44 \times 31 \cdot 185 \times 80 = 3{,}456{,}396 \text{ foot-pounds.}$$

This is thrown away at Chiswick on an average twelve times every day throughout the year, and a similar loss goes on where similar methods of pressing are adopted.

In the early part of the pressing-operation, a low pressure is just as effective as a high one, since the liquid has to be forced through the cloths only; and it is not till a considerable layer of solids has formed on the cloths that a high pressure is necessary.

Fig. 1.



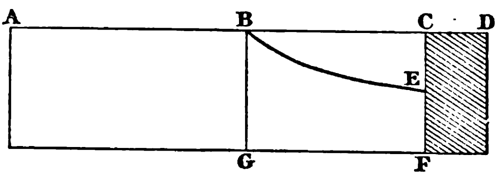
Taking advantage of this fact, experiments were made with two monte-jus to one press, so arranged that they were used as air-accumulator and monte-jus alternately. Calling the first monte-jus A B, and the second B D, let it be assumed that A B has had a charge of sludge forced from it by compressed air directly from the engine, and at the end of the operation the pressure in A B is 120 lbs. absolute pressure. While that operation is in progress, let B D be filled with sludge ready for forcing into the press. If, now, instead of blowing the air in A B to waste, it is admitted to B D, it will force the contents of B D into the press by its expansion. When this has been carried as far as economy will permit, the communication between A B and B D may be closed, and the remaining work in B D be finished by the engine forcing in fresh supplies of air. While this is being done, A B can be again charged with sludge, and the operation reversed, by expanding the air in B D into the monte-jus A B.

The gain from expansion in this way may be shown graphically by considering the two vessels as one cylinder, with a movable partition midway between its ends. Suppose the air in A B (Fig. 2)

has been allowed to expand into B D by removing the partition, and that it has expelled three-quarters of the sludge in B D by forcing the imaginary piston to a point C, then the pressure would be 68·66 lbs. in the two vessels. Making the diameter of the vessels the line of pressures above the atmosphere, and A C the line of volumes, the area B E F G represents the gain. In the case supposed, the economy expressed in foot-pounds is 955,878, or 27·65 per cent. of the energy stored in A B. As it is effected without any mechanism beyond a cock and a few feet of pipe, it is absolute gain to this extent.

It will be noticed that, after expansion has taken place, the monte-jus A B is still charged with air at 68·66 lbs. pressure, which is shut in when the communication between A B and B D is closed, and must be got out before A B can have a fresh charge of sludge. Instead of blowing this air in A B to waste, it may be made to do useful work by allowing it to expand to atmospheric pressure

Fig. 2.



behind a working piston. Experiments on this method of economising were made by allowing the air to expand in the air-compressor itself. This is a single-acting piston, with a valve in it which opens inwards. On the outward stroke atmospheric air fills the cylinder through the valve in the piston, and on the inward stroke the contained air is compressed and forced through another valve in the cylinder into the air-vessel. By allowing the waste air in A B to expand behind this piston on its outward stroke, its energy was expended in driving the piston, was stored up in the fly-wheel, and returned as part of the force necessary to re-compress the air in the cylinder, the steam supplying the remaining force necessary to raise the pressure to that in the working-vessel. When the pressure of waste air has been lowered in this way to atmospheric pressure, the steam has all the work of compressing to do as it had before the admission of the waste air.

For experiments with two monte-jus to one press, the monte-jus of the first press was used in conjunction with that of the second press, the latter being stopped for the time. No. 2 monte-jus

(corresponding to B D) being filled with sludge, had compressed air forced directly into it from the engine, all other cocks being shut off. Before all the sludge was forced into the press, the pressure rose to 105 lbs. on the gauge, and was maintained at that point till the pressing was completed. The water from the press was caught in a pit and measured 69⅛ cubic feet. The content of the press added to this makes 87⅛ cubic feet expelled from the vessel. The number of strokes made by the engine was 3,100. Communication with the press having been closed, the air in the monte-jus was blown down to atmospheric pressure in the ordinary way. The monte-jus was then filled with air again, to the same pressure as before, by 2,066 strokes of the engine. Deducting these from 3,100, leaves 1,034 strokes to do the work of pressing, and 2,066 to be thrown away. During the operation of pressing, over 200 cubic feet of air at atmospheric pressure escaped through the press.

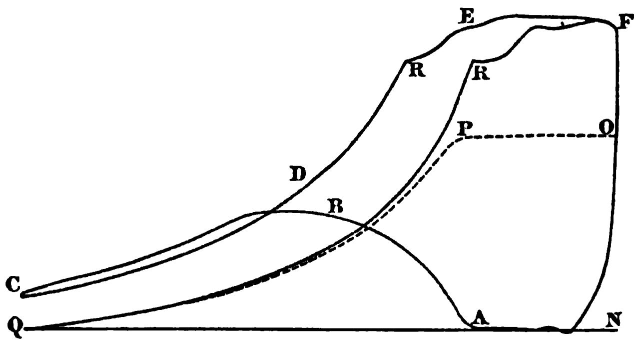
The monte-jus was again filled with sludge, and when ready for the pressure, air at 120 lbs. absolute pressure from No. 1 monte-jus was admitted. The vessels remained in communication till the pressure on the gauge was 52 lbs. above the atmosphere. The water expelled through the press by this expansion was 57½ cubic feet, which added to the contents of the press makes 75½ cubic feet of wet sludge expelled from the monte-jus. The loss of pressure due to fall of temperature and leakage was very small, as shown by the recorded pressure being only 1·66 lb. per square inch below what theory requires. The engine then forced air directly into the monte-jus, and the pressure rose to 105 lbs. on the gauge. When 87⅛ cubic feet had been expelled, as in the last experiment, it was found that the engine had made 1,500 strokes. That is to say, 1,500 strokes with the aid of the expansion from No. 1 vessel did the same work that without such expansion required 3,100 strokes.

With two vessels to each press this operation can be performed first with one and then the other, no air-accumulator being necessary. The economy of fuel may safely be put down at 25 per cent.

After these experiments, the air in No. 1 monte-jus (corresponding to A B) was admitted into the air-compressor. Owing to constructive difficulties the hole into the cylinder could not be made nearer the end than 3 inches, and consequently it was blocked up by the piston until it had made one-third of its outward stroke. The pipe conveying the air was also small, being only 1 inch in diameter, while the cylinder was 9⅛ inches,

and therefore the pressure in the cylinder could not be raised to much beyond one-half that in the vessel. The cut-off gear was a rough apparatus, consisting of a cock opened by the piston after it had blocked the hole, and shut by a weight released by a trigger, which the piston struck on its outward stroke. The full line Q R F in Fig. 3, was made by the air-compressor without waste air admitted. The curve A B C was made by waste air, which in this instance was not cut off early enough to allow it to expand to atmospheric pressure. The work represented by the curve A B C is 858 foot-lbs., which was stored up in the fly-wheel, and utilized as part of the force necessary to form the curve of compression C D E, and force the air out into the working monte-jus. Although the curve C D E shows that nearly 2 atmospheres were being sent into the monte-jus at work, yet when the curve

FIG. 3.



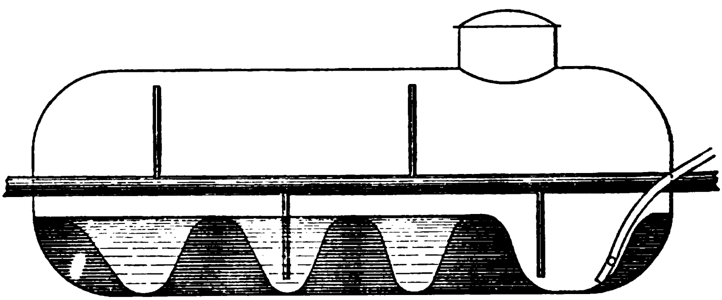
to be overcome by the steam is 3 lbs. per square inch less than when 1 atmosphere was forced in, without the aid of the waste air. The dotted curve N O P Q illustrates the gain which waste air of 60 lbs. pressure should give in theory, and with a specially constructed cylinder and gear that curve might be approximated to. It may be noted how completely the air enclosed in the air-compressor has been cleared out, as shown by the nearly vertical line F N. The break in the compression-curve at R is caused by a back-pressure valve in the delivery pipe.

This method of utilizing waste air might, perhaps, be more conveniently carried out by arranging an ordinary steam-engine cylinder behind the one in which the steam acts. The piston-rod and eccentric-rod would be lengthened so as to serve for both cylinders, and one connecting-rod would serve for both. The A B C has been deducted, the mean pressure against the air-piston

steam would be regulated by a governor, which would throttle it when the waste air was doing nearly all the work, and open the steam-valve as the energy of the air was used up. The exhaust steam could be used to keep the second cylinder hot, slightly increasing the pressure of the air, and preventing the formation of ice in the passages. The economy of fuel by these two methods is estimated by the Author to be about 50 per cent. of the present consumption.

There is a defect in the plant at Chiswick which it may be worth while to point out. The monte-jus, or pressing vessel, is laid horizontally, the pipe to the press entering it at one end. This arrangement favours an accumulation of lime and sludge in the vessel to such an extent, that it is nearly always necessary to draw in three charges of wet sludge to fill the press twice with

Fig. 4.



cake. Great loss of time results, in addition to the loss of fuel. Fig. 4 shows how the accumulation forms between the arms of an agitator which traverses the vessel. The spaces between the dams of sludge are left filled with water which cannot be forced out. The revolving shaft also winds on to itself hair, rags, and fibrous matters, which abound in sludge, and further diminishes the space in the vessel. If the vessels are not washed out, the accumulation will go on till over one-half of the whole space is occupied. The vessels are washed out with a hose pipe about every fourteen days, and a man has to get in every time to clear the shaft.

The following results of a year's pressing at Chiswick may be of interest. The population using the sewers is 18,000. Rainwater is taken from half the roof area of three thousand five hundred houses; road- and street-water is excluded. The sewage is treated with lime and sulphate of alumina.

	Amount per day in Tons.	Amount per Annum in Tons.	Amount per million Gallons of Sewage in Tons.	Amount per head of Population per Annum in lbs.	Cost of Pressing per Ton.
					s. d.
Wet sludge . . .	33	12,045	46·25	1,499	0 10
Pressed sludge . .	6	2,190	8·50	272·53	4 7

The details of cost per annum for pressing are :—

	£.
Labour	250
Lime	140
Cloths	63
Coal, gas, oil, &c.	50
Total	503

The following Table shows the flow of sewage, the depth of rainfall, and the amount of sludge, for each month of 1885, from the 16th of February, when the pressing plant was taken over by the Local Board.

Month.	Days.	Sewage.	Rain.	Pressed sludge.
		Gallons.	Inches.	Tons.
February	12	11,600,720	1·585	61
March	31	21,242,000	1·160	106
April	30	20,470,450	1·830	168
May	31	22,096,390	2·167	274
June	30	22,248,380	1·690	184
July	31	18,517,050	0·385	192
August	31	17,799,510	0·810	182
September	30	20,940,150	3·895	194
October	31	21,155,940	2·720	191
November	30	24,103,820	2·690	179
December	31	25,850,190	0·940	191
	318	226,024,600	19·872	1,922

The Paper is accompanied by four diagrams, from which the Figs. in the text have been engraved.

(*Paper No. 2215.*)

"Administration of Fishing-Boat Harbours in France."

Summary of information collected by the SECRETARY.

PARTICULARS relating to the method of construction, the nautical condition, and the cost of construction and maintenance, are given for the fishing-boat harbours, as well as for the other harbours of France, in the official publication entitled "Ports Maritimes de la France."

Expenditure in Construction.—The whole of the sea-coasts and inlets, and all natural and artificial harbours in France, belong exclusively to the State. The State alone constructs harbours, and alone extends and improves them. In principle, all the costs of construction and improvement are defrayed by the State out of the general revenues of the budget, not by local taxation. Nevertheless, some years ago, as the requests for improvements became very numerous, the State decided to require the localities to contribute towards the expenses; and, accordingly, most of the improvement works decreed within the last ten years have been paid for by the State, aided by local subsidies which vary, according to circumstances, between a third and a half of the total expenditure. These subsidies are paid, either by the departments or the municipalities interested, in the case of small ports not possessing a Chamber of Commerce, or by the Chamber of Commerce in the case of large ports, or of those of moderate importance. The subsidies relating to small fishing-boat harbours are generally of limited amount; and the departments and municipalities which contribute raise them out of their ordinary revenues. The subsidies contributed by the Chambers of Commerce for the larger harbours are obtained by loans borrowed by the Chambers, which are authorized by an Act, or by an Order in Council, to levy a local tonnage-due on the vessels entering the port during all the period necessary for the redemption of the loan; but French fishing-boats are invariably exempted from these local dues. Only a few harbours have these local tonnage-dues for guaranteeing the special loans raised for local improvements; namely, Dunkirk, Calais, Boulogne, Treport, Dieppe, Fecamp, Havre, Rouen, Honfleur, Cherbourg,

St. Brianc, Paimpol, Rochelle, Bordeaux, Oran, Algiers, Bona, and Philippeville.

Expenses of Maintenance.—The cost of the maintenance and repairs of harbour-works as well as the salaries of the engineers and their assistants, of the lock-keepers, watchmen, harbour-masters, and other port officials, and the attendants on the lighthouses and beacons, &c., are wholly paid by the State out of the taxes, without any local contributions.

Harbour-Dues.—The State levies, at all ports, an entrance-due, called *droit de quai*, of half a franc (4·8*d.*) per ton of registered tonnage on all vessels, both French and foreign, coming from foreign ports of Europe or the Mediterranean; or of one franc (9·6*d.*) per ton on all French and foreign ocean-going vessels. Fishing-boats and coasting-vessels are exempt from all dues. The above quay-dues are the only State impost levied on navigation in French ports; they do not nearly cover the expenses of maintenance, large repairs, and superintendence. Moreover, the receipts from these dues are paid into the Treasury, without any special allocation, where they are mixed up with the total revenues derived from all the other taxes, such as customs, excise, land-taxes, &c. On the other hand, the expenditure on harbours is defrayed from the general revenues of the budget; and the distribution of the total sum granted by Parliament each year for harbours is made by the Minister, taking into account the stated needs of each port, and the general public importance of its preservation or improvement, without any reference to the amount of quay-dues which the port may bring in to the State.

The exemption of fishing-boats in every port, not only from State dues, but also from all local dues without exception, is not owing to a general law, but is a stipulation hitherto inserted in all special Acts and Orders for the levying of dues in certain harbours, and it is possible that this rule might be departed from in the future. The improvement-works of the large harbours, for which these local harbour-dues have been authorized, were specially undertaken for the sake of merchant-vessels, and not for fishing-boats. If, however, it was determined to execute some large work for the special advantage of fishing-boats, the Act decreeing it might, without violating any legal principle, authorize the levying of local dues on fishing-boats, by the Corporation aiding the State with a subsidy to secure a more prompt execution of the works. Nevertheless, up to the present time, no such case has occurred, and in no port do fishing-boats pay any tonnage-dues, nor are any dues levied on the fish landed.

Regulations for the Use of Ports by Fishing-Boats.—There is a general code of police regulations applicable to all French ports.[1] These regulations are binding on fishing-boats equally as on merchant-vessels. Nevertheless, in practice, fishing-boats are exempted from the declaration (mentioned in Article 3) of various particulars relating to the vessel, which has to be delivered in writing on entering and leaving a port.

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[1] "Règlement Général pour la Police des Ports Maritimes de Commerce." A copy of this document is deposited in the Library of the Institution.

(*Paper No. 2217.*)

"Central-Station Electric Lighting."

By KILLINGWORTH W. HEDGES, M. Inst. C.E.

UNCONTROLLED financial speculation, aided by the stringent clauses of the Electric Lighting Act of 1882, have been a great deterrent to the extension of old, or the introduction of new, schemes for the supply of electricity to the public in the same manner as gas. Of the one hundred and six applications for Provisional Orders which were made towards the end of the year 1882 by various corporations, local boards, vestries, burghs, boroughs, imperial commissions, urban sanitary authorities, and electric-light companies, there is not a single installation at present supplying electricity under the Act. On the Continent and in the United States, where each city legislates for itself, electricity is in a very different position, and central-station electric lighting is either established, or about to be started, in every important town. In the United States there were, in 1886,[1] forty-one Edison central-lighting stations alone, supplying over one hundred thousand lamps, and there are many other systems; in fact, the subject is so large that the Author proposes to treat in this Paper with what has been accomplished on the Continent and at home. Travellers abroad are accustomed to find electric lighting installed in the most out-of-the-way places, especially in Switzerland, where water-power is abundant and is utilized to generate electricity, so that in small hamlets arc lighting is often employed, and the visitors to the local hotel will find it lit throughout by electricity. Electric-light stations in England are small in comparison with those on the Continent. The largest is that at the Grosvenor Gallery, London, which has been successfully maintained for some time, and now supplies three thousand glow lamps on five circuits, the total length of which is 9 miles. The next largest is the station at Brighton, from which small installations both of glow- and of arc-lights are supplied to all parts of the borough. That the question of cost or trouble, and the annoyance of machinery when erected in a dwelling-house, do not altogether prevent

[1] Report of the Select Committee of the House of Lords, Electric Lighting Act, 1886. Appendix B.

the adoption of a superior light, is clearly proved by the increasing number of householders who, after waiting in vain for electricity to be brought to their doors, have set up the plant necessary to produce it themselves. There are also many important public works where electric light has been exclusively adopted. For instance, at the Tilbury Docks there are one thousand three hundred and fifty glow- and eighty arc-lamps, distributed over an area of 300 acres, and including the lighting of an hotel, dock sheds, warehouse, signal-boxes, and offices. The London, Chatham and Dover station at Victoria has also been electrically lighted by glow lamps for the past three years, the current being obtained from a central station, which was erected for the purpose of supplying electricity to the Victoria district, and for which a Provisional Order was obtained. This, however, has since been abandoned, although £16,000 had been expended on plant and buildings by the promoters, who preferred to postpone the scheme rather than to submit to the onerous twenty-seventh clause of the Electric Lighting Act. Another still larger installation has been put down to supply electricity to the Paddington station and district of the Great Western Railway, as far as Westbourne Park. It embraces an area of 67 acres, and is lighted by four thousand one hundred and fifteen glow and ninety-eight arc lamps. The system adopted is that designed by Mr. J. E. Gordon, and has now been successfully worked for some time; but the many accessories which are introduced, such as telephones, telegraphs, and indicators, make it complicated in comparison with gas, or even with the ordinary electric-light systems. The current is generated by two dynamos, each weighing 45 tons, and having revolving-magnet wheels 9 feet 8 inches in diameter, 22 tons in weight, a third machine being kept in reserve. These dynamos are separately excited, and produce alternating currents. The electricity is led to a large switch-board for distribution throughout the district by means of five sub-stations; and from this board there branches a double system of mains, which run everywhere side by side, one-half the mains being connected to the first machine and one-half to the second, so forming an excellent arrangement for the prevention of total extinction of the light. The mains running to the sub-stations are on the divided system, which is introduced for the purpose of saving copper, as in a solid cable the loss of pressure is greatest when the full number of lamps is on, and decreases as the lamps are extinguished.[1] With the divided main

[1] Journal of the Society of Telegraph-Engineers and Electricians, vol. xii. 1883, p. 551.

system it is intended to follow out Sir William Thomson's formula, which equates the value of the loss of head, and the interest on the saving on the copper. If for a certain main this formula shows that a fall of 20 per cent. is the most economical condition for working, then, since by the divided main the pressure can be kept within a variation of 2 per cent. at the distant end, it follows that a considerable saving can be effected over an ordinary solid main. Special arrangements are adopted at Paddington to keep the pressure constant, a fall of potential being allowed for; thus at the engine-house the pressure is 150 volts, in the passenger station it is 120 volts, and at Westbourne Park it is 100 volts. The arc lamps are fed by the same mains, and are arranged two in series.

The problem of electric lighting from central stations is comparatively easy if an area can be obtained immediately surrounding, and within a short distance of, the station, with a right of way for laying down the electric mains direct. This happy state of affairs has not yet been attained, consequently the generating station has more often to be in an out-of-the-way corner of the district to be lighted, and it would be financially impossible to use low-tension currents with correspondingly large mains. The difficulty has been overcome in several ways by the use of high-tension currents in the mains, and has led to the adoption of secondary generators or transformers of electricity, which by induction supply a current of low potential in the house-service. The first to make this plan a practical success was Mr. Gaulard.[1] His system is adopted in the Grosvenor Gallery installation; it is also being extensively used abroad, where there are other equally successful methods of employing induced currents.

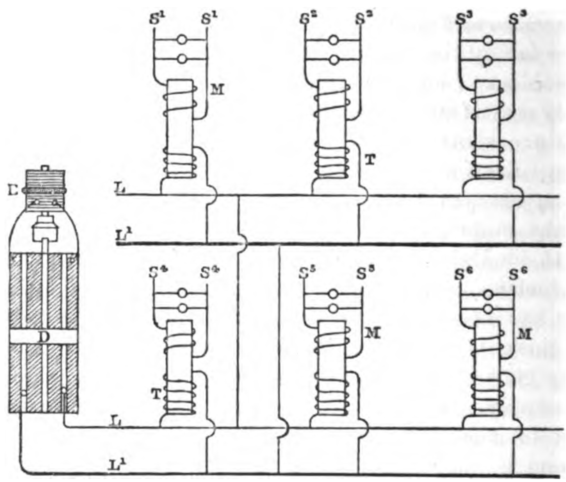
Fig. 1, p. 400, represents the arrangement of primary and secondary circuits.

An alternating current is sent through the main, which is a closed circuit, and a small portion is drawn off wherever there is a secondary generator or transformer; these instruments are placed in parallel between the conductors in the same manner as a glow lamp, neither main can be called positive or negative, as the current flows backwards and forwards many times in a second. The house wires are joined to the secondary circuits, and are quite distinct from the main, which they do not even touch, although sufficiently near to receive an induced current alternating the same as the primary, but of a much lower electro-motive force. In the Gaulard system the transformers are constructed with a

[1] Minutes of Proceedings Inst. C.E. vol. lxxxiii. p. 535.

number of copper disks or washers; these are placed alternately primary and secondary in a vertical frame, through the centre of which an iron core is fixed, consisting of a bundle of straight iron wires. The core is movable in the coil in the manner of the well-known induction-coils, and thereby the electro-motive force of the secondary current can be adjusted. The magnetic lines of force pass through the core, in at one end and out at the other, and are then more or less disseminated through space; it will thus be seen

FIG. 1.



D, alternating-current dynamo;
E, continuous-current dynamo for exciting;
L L[1], main primary conductors;
M M, secondary conductors;
T T, transformers;
S[1] S[2] S[3] S[4] S[5] S[6], lamps in parallel.

that the path of the lines lies partly in iron and partly in air, and since air has about seven hundred times more magnetic resistance than iron, it is evident that the number of lines created with a given current must be considerably smaller than would be the case if the path of the lines contained iron only. This is the case in the Zipernowsky-Deri-Blathy[1] system of transformer, which has coils similar to the Gaulard, but with the iron of the core applied in the form of a ring-shaped shell, surrounding both coils completely. This arrangement can best be described by comparing it to a Gramme armature, in which the copper and the

[1] Minutes of Proceedings Inst. C.E. vol. lxxxiii. p. 537.

iron have changed places.' Imagine what is usually the core in an armature replaced by the primary and secondary coils, and instead of the winding of insulated copper wire, wind iron wire around the coils, and one of these transformers is the result. In consequence of the lower magnetic resistance of the transformer, as compared to the secondary generator, the electrical output obtainable with equal weights of copper and iron appears to be considerably greater in the former apparatus. Professor Feraris, of Turin, has published[1] some of the results of comparative experiments made with transformers and secondary generators, and finds that the coefficient of induction is 3·6 times as great with the former as with the latter.

The Grosvenor District Electrical Supply Company's installation may be described as illustrating the practical working of the secondary generator system. The machinery is fixed on a basement excavated under the Grosvenor Gallery; the foundations are of massive concrete, in which stone supports for the engines and dynamos are embedded; the concrete does not touch the walls of the building, but a space of about 1 foot is left, which is filled in with clay; and by this simple plan all vibration of the machinery is isolated from the building. The power is obtained from two horizontal high-pressure non-condensing engines, each of 35 nominal HP., running at a speed of 55 revolutions per minute, which is maintained constant by means of a governor directly attached to the expansion slide-valve. The two engines drive a countershaft, which is in two lengths coupled by a conical friction-clutch; this permits of either length being started or stopped without interfering with the other. The speed of each engine is checked by means of a liquid speed-indicator, designed by the Author.[2] Two Siemens alternating-current[3] dynamos of the W–100 large type are driven by belting, one dynamo from each length of shafting; they are excited by two continuous-current machines, the circuits from which are joined to a regulating apparatus, which by altering resistance keeps the electro-motive force of the large machines proportional to the number of lamps which are to be maintained. At present, hand regulation is employed, but it is proposed to use an automatic regulation similar to that which has been successfully used at the Gaulard installation at Tours. The current from the machines is at a potential of 2,400 volts, and

[1] Zeitschrift für Elektrotechnik, Vienna, 1885. Also "Abstracts," Minutes of Proceedings Inst. C.E. vol. lxxxiii. p. 537.

[2] Minutes of Proceedings Inst. C.E. vol. lxxxiii. p. 260. [3] *Ibid.*, p. 178 *et seq.*

that from the transformers is 100 volts. The primary wire which carries this high electro-motive force does not enter the houses, as the transformers are, as a rule, fixed in the cellars, and from them the house branch, is led in the form of a cable of fine wires, having a total diameter of $\frac{7}{16}$-inch; the lamps, which are placed in parallel across this cable, are attached to single No. 18 or No. 20 B. W. G. wires in the usual manner. When first established, the transformers presented an element of danger, in that they in common with all induction-coils were also condensers, and therefore a dangerous shock might be given to any one touching some unguarded portion of the lighting system. This objectionable feature has been prevented, by uniting the poles of the inducing and induced circuits at the transformer by a metallic high resistance, so that no static charge capable of interfering with the safety of the system can be produced. The primary-current conductor is led overhead, and still remains an objectionable feature of the system, although the original trouble with the neighbouring telephones and telegraphs has been overcome. The primary circuit is a small carefully insulated cable of high-conductivity copper wire, nineteen strands of No. 15 B. W. G.; it weighs about $1\frac{3}{4}$ ton per mile, and is suspended where it crosses the streets on a steel bearer whose tensile strength is $1\frac{1}{2}$ ton. It is so arranged according to the droop of the cable that the strain of the bearer never exceeds 225 lbs. which means that the factor of safety is nearly 12 to 1. Double cut-outs[1] or safety-fuzes of the Author's design are placed on each pole of the primary, at the point where it enters the house, so that in the case of an excess current, the mica-foils would fuse, and all connection between that house and the supply main would cease. The installation was designed by Messrs. Brougham and Mackenzie, acting in co-operation with Mr. Gaulard.

The other lighting-stations mentioned in Appendix I do not present any specially novel features, with the exception of that at Brighton; it is on a plan similar to the Temesvar installation which the Author proposes to describe as representative of the multiple-series system.

It will be found on examining Appendix II, that by far the larger number of lamps are maintained from stations employing the Edison system, the Gaulard plan of using transformers comes next, closely followed by the Zipernowsky, and the high-tension multiple-series comes last.

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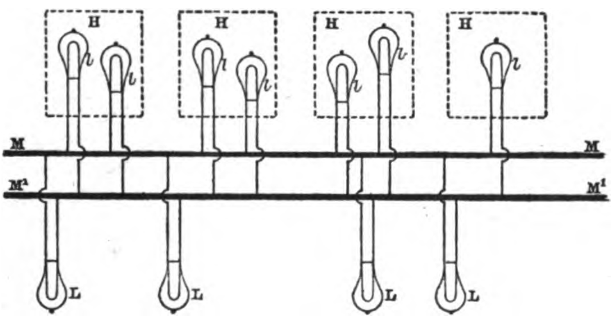
[1] Minutes of Proceedings Inst. C.E. vol. lxxxix. p. 19.

The Edison system has frequently been discussed, in connection with small installations, but in magnitude the stations in Berlin and in Milan exceed anything that has been started here.

Before describing the central electric-light station at the latter city, it may be well to recall to mind that the Edison plan is the combination of a number of machines which pump electricity into a network of feeders, mains, and conductors, the lamps being placed in parallel circuit as shown at L *l*, Fig. 2, and maintained at a constant potential of 110 volts.

M M′ are the flow and return mains, the dynamos bridging them across at one end. If the mains were very long, those near to the dynamos would be exhausting the supply, and the lamps at the remote end would not get the full pressure. A system of

FIG. 2.



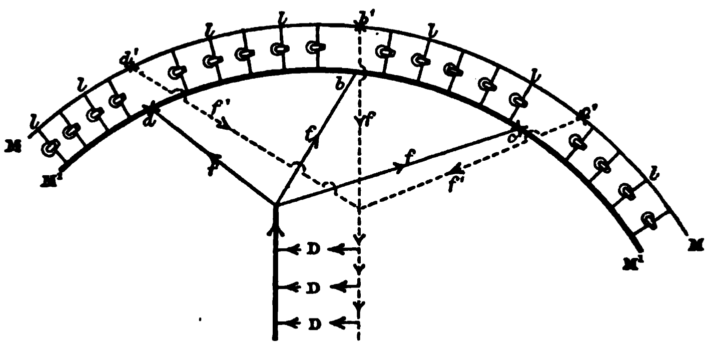
feeders has been devised so that each lamp, no matter where it may be, shall have approximately the full 110 volts working through it. Fig. 3, p. 404, shows a long circuit consisting of two branch mains bridged by a large number of lamps *l l*, and D D are the dynamos at the central station. Series of feeders *f f′* have to be taken from the dynamo mains and fed direct into the branch mains at various points *d d′*, *b b′*, *c c′*, in order to distribute the electrical pressure equally.

The Santa Radegonda station at Milan is at the present moment the largest in Europe; the building, which was formerly a theatre, is well adapted for the work required; the dynamos and engines are fixed in a deep basement, while the boilers are a few feet above the street-level, the upper floors being used as stores and testing-rooms. The dynamos, eight in number, are of the old Edison type, with horizontal magnets [1]; seven of these

[1] Minutes of Proceedings Inst. C.E. vol. lxxxiii. pp. 232, 233.

machines are connected to the feeders which supply the mains, and these cover the district to be lighted on the Edison network system. The motive power is furnished by six Armington-Sims, and two Porter-Allen engines, each connected direct to the armature of a dynamo, the speed being maintained at the uniform rate of 350 revolutions per minute, except in the case of the spare engine and dynamo, which is kept turning slowly ready to be switched on should occasion demand. The starting or cutting out of circuit of these large machines requires some care. In the first place, to start, it is necessary to insert resistance into the shunt circuit of the dynamo, which is done by a switch; but to throw 150 HP. into the main circuit would be dangerous to the lamps, so that the current is first sent into a bank of one thousand lamps

FIG. 3.



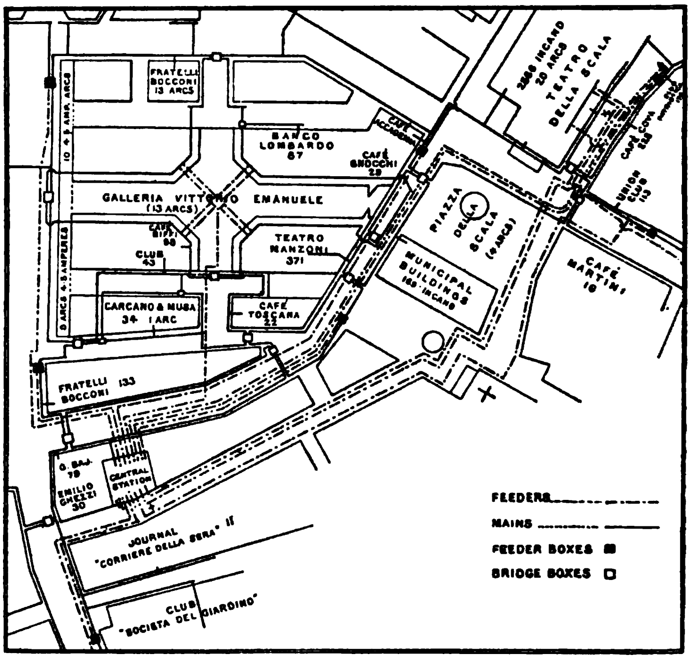
used as a resistance, and these are cut out step by step; similar care is taken when a machine is stopped. To control the electromotive force, which varies greatly from time to time, hand regulation is used during the day, with the help of the Edison tell-tale, consisting of two lamps, a red and a white one, which light up when the current is high or low; but when the night service comes on, as it may happen that two thousand lamps may be turned out at once, an attendant has to carefully watch the electric regulator, and be ready to insert resistance into the field-magnet circuits by moving a wheel connected by a shaft and bevel-gear to a system of commutators. The principal difficulty to be overcome, in an installation where the current is distributed over a large area, is the regulation of the electro-motive force at the various points, as at Milan; there are no return galvanometer wires, which are now used in both the two- and the three-wire Edison systems in the United States.

The plan devised by the Company's electrician at Milan is very ingenious, and enables the pressure at the ends of the various feeders to be kept practically the same, although they are of different lengths and sectional area. In the first place, resistance was added to each feeder to equalize the resistance in each conductor; and in order to provide for the varying amount of current the feeder has to supply, a peculiar form of commutator, having a guillotine-shaped contact-piece, was inserted in the circuit. By moving this, suitable resistance is inserted or cut out, and the attendant having a series of numbers, has only to set this instrument to the number shown by the ampere meter. By far the largest amount of current is drawn off for the lighting of the Scala Theatre, the stage lighting alone taking more than one thousand lights; if these were all turned on suddenly, the other lights in the district would be dimmed; to obviate this, auxiliary feeders have been run, which are used only when any great increase is expected; commutators similar to those referred to above also regulate these feeders without any special attention. The pressure at any point in the system is by this means easily controlled, and affords an illustration of what is perhaps not the most economical, but is found to be the most practicable, way of maintaining a constant potential in a district, where the amount of output of current is suddenly doubled. Fig. 4 (p. 406) is a plan of the net-work system of conductors laid through a large portion of the city; the conductors are in outward appearance similar to gas-pipes, the current passing through semicircular bars of copper, imbedded both for the flow and return in the same iron tube, which is laid underground in a shallow trench. The house-supply is drawn from the mains, and these are connected to the feeders by means of ordinary junction-boxes, which each contain a fusible cut-out. The bridge-boxes allow of expansion of the line, and have connections for testing purposes. The insulation is extremely good, mainly on account of the favourable nature of the ground, which is chiefly gravel; no trouble has been experienced with leakage, nor has the service ever been interrupted. The cut-outs are of an improved Edison form, but have the disadvantage attending all lead plugs where the current is great, in that, to guard against accidental melting due to the heating effect of the current, the sectional area of the lead has to be much larger than would be otherwise necessary.[1] In fact these cut-outs will protect the cable against a bad short-circuit, but against nothing else.

[1] Minutes of Proceedings Inst. C.E. vol. lxxv. p. 106.

In addition to the glow lamps, eighty arc lamps are worked in derivation, two in series; most of these lamps require 45 volts, to which 10 per cent. of idle resistance is added, constituting a total loss of current which is extremely low for a combined arc and incandescent system of lighting. The service commenced in 1882 with a little over one hundred lamps, and at present there are nearly ten thousand glow lamps, and soon one hundred arc

Fig. 4.



lamps will be in use. At first the new enterprize had to struggle against very great difficulties; not only the technical difficulties of distribution by means of a network of feeders and mains had to be overcome, but also those arising from the prejudices of consumers and the competition of the Gas Company, who tried to deter consumers from introducing electric light into their houses. One of these means consisted in offering to the private consumers resident in the district, which was threatened by competition with electricity, an agreement by which the Gas Company bound itself to supply gas at *5s.* 8½*d.* per 1,000 cubic feet, instead of *7s. 7d.* as charged hitherto; and even now those inside the "charmed circle"

of the electric-light conductors get their gas cheaper than the public outside. One of the reasons which accelerated the adoption of electric light was the introduction of the Edison meter, in consequence of which consumers could be charged exactly for the amount of light they had received, and were relieved from paying a lump sum according to the number of lamps fixed, which was customary in the early days of the Company. The prices at which the Company now provides light, at all hours of the day and night, are as under:—

Type of Lamp.	Installation charge per lamp.	Charge per lamp-hour.
	s.	*d.*
10-candle	18	0·26
16- "	28	0·40
32- "	56	0·80

That is, a little over ½*d.* per ampere-hour; the 10-candle lamps requiring 0·5, the 16-candle lamps 0·75, and the 32-candle lamps 1·5 ampere.

The Company lends meters for fifty, one hundred, and one hundred and fifty lamps, at an annual rent of 4*s.* 10*d.*, 7*s.* 3*d.*, and 9*s.* 7*d.* respectively; and replaces, without charge to the consumer, any lamp the filament of which has broken, but it does not replace lamps where the glass is broken. For arc lamps requiring 9 to 10 amperes, an annual rent of £2 must be paid for the lamp itself, and a charge of a little over ½*d.* per hour for every ampere-hour. The carbons are charged for at 1*d.* per pair, lasting for about seven hours. Now that the installation has been in use for several years, and that the Company has arrived at a very accurate estimate of the time during which an average consumer requires the light—about one thousand six hundred lamp-hours per annum—it proposes to simplify the method of charging large consumers, by omitting the initial charge of each lamp, and, instead, to charge 0·6*d.* for each 16-candle lamp-hour.

The Edison meters are based on the electrolytic action of a small fraction of the current which passes through the meter. They are cells, with rectangular zinc plates immersed in a solution of sulphate of zinc of 1·054 density, the distance between the plates being a little over ¼ inch. The proportion of the current which passes through the meter, to that which passes directly into the consumer's house, is 1 to 973. The resistance of the shunt circuit is 9·75 ohms, made up as follows: cell, 1·75 ohm; metallic portion, 8 ohms. The resistance of the metallic portion rises with the temperature, whereas that of the cells falls with a rising temperature; and in this manner, the small variations of resistance

which might take place in the cell are counterbalanced by the equally small variations in the resistance of the metallic portion. A complete meter consists of two similar-sized cells of the same resistance, placed in series. The object of employing two cells is, that when little current is passing, as in the summer months, one cell alone is used, and when the consumption is sufficiently large both cells are employed, and the mean between the two indications is taken as the basis for calculation in number of ampere-hours. The quantity of electricity passed through the cell is calculated by the loss of weight which has taken place in the positive plate. An employee of the Society visits every meter monthly, taking away the old cells and substituting others freshly constructed. A book is kept in which the weights of the new plates and those of the returned plates are entered, and on the basis of these entries the accounts are made up. The largest plates are those in the 100-light meter, and are intended for a maximum current of 75 amperes in the main circuit; they are 6 inches long by 2 inches wide. In cases where a larger amount of current is taken, the capacity of the 100-light meter is increased by joining two or more copper strips across the terminals of the cells. The weak point of the system is the removal of the cells, which leaves the adjustment of the account to be paid entirely in the hands of the Electric-light Company; in spite of this drawback, there has not been a single complaint from consumers during the two years in which the meter system has been in use.

The Gaulard System of Secondary Generators.

An important installation at Tours of three thousand five hundred lamps has been for some time successfully working; but another at Tivoli, which has been recently opened, has some additional points of interest, in that the natural power of a waterfall is applied to generate electricity. Two turbines constructed by Escher Wyss, of Zurich, having an available head of 29·75 feet, give 80 HP. each, which is employed to drive two Siemens alternating-current dynamos, separately excited by two small continuous-current machines. Two distinct circuits of chromo-bronze naked wire, 3·7 millimetres in diameter, are run overhead, in the same manner as telegraph wires, through the town for a total length of about 19 miles. The street lamps are fixed alternately on each circuit, so that one-half can be extinguished at a late hour without interfering with the others, or having to turn out individual lamps. The number of lamps used in the streets is two hundred glow lamps of 50-candle-power, also

one hundred and twenty glow lamps of 16-candle-power for the illumination of the narrower streets. Arc lamps are also used, as well as a large reflector lamp, the rays from which are turned on the Temples of Vesta and Sibilla. A house-to-house system is also being established; and the company which has put up the work proposes to utilize the falls of Tivoli in order to transmit 2,000 HP. for lighting purposes in Rome.

The Zipernowsky-Deri-Blathy System of Transformers.

The firm of Ganz, of Budapest, has recently started a similar installation in order to light a portion of Lucerne. The water-power of Thorenburg, 3·1 miles off, is used to work the turbines, which drive two self-exciting alternating-current dynamos of the Ganz type, similar to those shown at the Vienna Exhibition in 1884. The primary current of 38 amperes at an electro-motive force of 1,800 volts is led by four uncovered wires, each 6 millimetres in diameter, to the first station, which is 2·4 kilometres distant; here 1,500 watts are taken off, and at 2·3 kilometres further 7,000 watts are utilized in two of the hotels at Lucerne. A large installation on the same system has been put down in Rome, and several continental cities are adopting this method of supplying electric light by small overhead wires. An advantage, claimed by the Zipernowsky system, is the method of keeping the strength of the magnetic field of the dynamos in accordance with the external demand for current. The regulating apparatus employed consists of a small transformer, the primary coil of which is traversed by the whole, or by a proportionate part, of the main circuit, while the secondary coil is inserted into the exciting circuit. Thus, if the main current increases, the exciting current induced in the two armature coils of the dynamo is reinforced by the inductive action of the regulating transformer; and the field of the dynamo is strengthened when more current is required. The opposite takes place when, through the extinction of lamps on the external circuit, the demand for current becomes less. In an experiment made with the transformers, which supply some five hundred electric lamps for the Teatro dal Verone and adjoining houses at Milan from the central electrical station ¾ mile away, the main current was often found to vary from 1 ampere to 35 amperes, but no variation in the service pressure could be detected, and the lamps burnt with equal brightness whatever the number in use. In the experiments at the Teatro dal Verone each transformer worked its own independent circuit of lamps; but if the

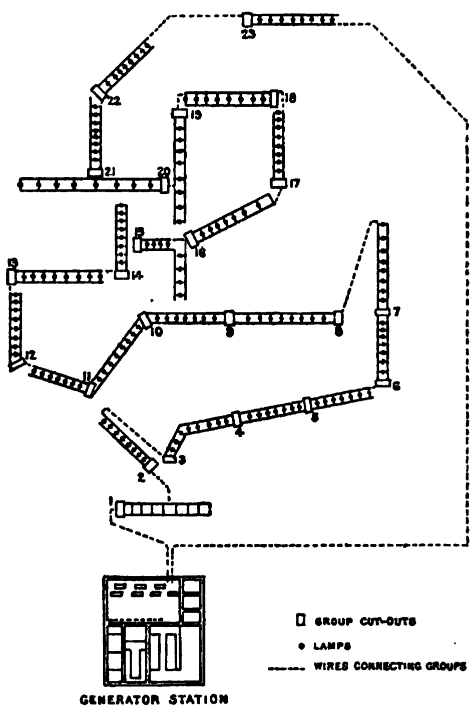
conditions of the different circuits were alike they could be coupled up together in any manner desired, and thus a group of transformers could become a centre of distribution.

THE MULTIPLE-SERIES SYSTEM.

This method of using high-tension current has already been referred to in connection with the house-to-house lighting at Brighton, and is being employed on a small scale for central-station supply in other English towns. The electric lighting of the town of Temesvar, in Hungary, is on a far larger scale, and has, from November 1884, successfully superseded a combination of gas for the more important streets, and petroleum for the outlying ones, the total cost of which was 26,480 florins per annum. A twenty-four years' concession was given to the International Electric Company, the plant remaining their property at the expiration of the term, subject to purchase by the municipality at their own valuation. The public lighting is stipulated to be effected by means of seven hundred and thirty-one glow lamps of the intensity of 16-candle-power; but the option is given to the company of switching out a fixed proportion of these lamps at 11.30 P.M., or of leaving the whole number in operation with their light intensity reduced from 16- to 8-candle-power from 11.30 P.M. till dawn. The total number of lighting-hours per annum is three thousand five hundred and ninety-seven and a half for the lamps which are in operation from dusk until dawn, and eighteen hundred and sixteen for those which are extinguished at 11.30 P.M. The price fixed in the concession for public lighting is 1·5 kreutzer per 16-candle-power lamp per hour, equal to 53 florins 95 kreutzers per lamp per annum of three thousand five hundred and ninety-seven and a half hours, or 27 florins 24 kreutzers per lamp per annum of eighteen hundred and sixteen hours. The company has found it more convenient to exercise the option reserved to it, of keeping all the seven hundred and thirty-one lamps in operation from dusk till dawn, reducing their light-intensity to 8 candles after 11.30 P.M.; and the municipality has agreed to pay a round sum of 29,000 florins (£2,416 13*s.* 4*d.*) per annum for this lighting, and 41·95 florins (£3 10*s.*) per annum for each additional lamp worked in the same way. Comparing these figures with what precedes, it will be found that the electric lighting of the streets now in operation costs 2,520 florins more than it did on the former plan of combined lighting, partly by gas and partly by petroleum. On the other hand, the streets are lighted throughout with 16-candle-

power lamps from dusk until 11.30 P.M., and with 8-candle-power lamps from 11.30 P.M. until dawn. For electric light supplied to private consumers the concession fixes the price at 1·81 kreutzer per 16-candle-power lamp per hour, or 0·1131 kreutzer per candle per hour, with the right to charge 15 per cent. more for lamps of less intensity than 16 candles. In all these prices the renewal by the company of lamps failing from legitimate wear is included.

FIG. 5.



MULTIPLE-SERIES LIGHTING. TEMESVAR.

One central generating station has been provided for the whole town, from which at present four distinct circuits have been laid, each fed by a separate dynamo. The street lamps are connected up in "multiple series," that is to say, in groups placed in series on the circuit, the lamps in each group being connected up in parallel.

Fig. 5 shows the arrangement diagrammatically. Each group consists of eight lamps in parallel; at present three of the circuits

have twenty-four groups in series, and the fourth circuit has twenty-three groups in series, giving a total of ninety-five groups, comprising seven hundred and sixty lamps, of which seven hundred and thirty-one are public lamps and twenty-nine are used at the central station. To meet the risk of interruption in any circuit through the failure of individual lamps, an automatic switch is arranged so as to put in a reserve lamp, in the event of a whole group being interrupted. Another self-acting device will short-circuit the whole group, so that the other groups in the circuit will be unaffected. The automatic lamp-switch is contained, together with the reserve lamp, in the lantern, and the automatic group cut-out consists simply of an electro-magnet with a coil of high resistance connected up in parallel with the group of lamps it protects. These appliances have been found to work well. The main conductors are formed of insulated single copper wire, 4·6 millimetres in diameter; they are carried overhead on porcelain insulators, fixed to telegraph posts or to wooden arms let into the walls of houses; the resistance of this conductor is about 1·1 ohm per kilometre. The glow lamps are placed in reflectors at an angle of about 45° from the vertical, and are carried on brackets either fixed to the walls or on special cast-iron posts. They are of the Lane-Fox type; although originally intended for 16-candle-power lamps, they have been so far worked at 18 candles, taking 1·183 ampere, or 3·5 watts per candle-power. The current is maintained at 10 amperes, and the potential between independent groups of lamps is 53·6 volts. The aggregate energy lost, in overcoming the resistance of the main leads, switches and cut-outs, is 12·8 per cent. of the total electrical energy generated at the central station—a very satisfactory result on a system of over 37 miles of streets. The electro-motive force in the conductors is about 1,400 volts, which is below the normal capacity of a Brush machine,[1] thus allowing more lamps to be operated from the four machines. The machinery is driven by a 300-HP. horizontal compound-condensing tandem steam-engine, running at the normal speed of 100 revolutions per minute. During the first twelve hundred hours of lighting, only three lamps out of the seven hundred and sixty failed, and one of these had been broken maliciously. The engineering arrangements are due to Mr. C. F. de Kierskowski Steuart, M. Inst. C.E., the various difficulties incidental to a novel work having been surmounted with inexperienced workmen. Although the system at Temesvar has more complicated arrangements than are now required if secondary generators are used, it has

[1] Minutes of Proceedings Inst. C.E. vol. lxii. p. 339.

shown that it is quite practicable to light all the streets in a town by electricity; also it has enabled a comparison to be made between the useful effect obtainable from arc and from glow lamps. Each group of glow lamps was found to absorb practically the same energy as one arc lamp of from 800- to 1,000-candle-power, and ninety-one or ninety-two of these could have been run with the same expenditure of power as seven hundred and thirty-one glow lamps. The eight glow lamps forming one group are in many cases scattered in different streets, often quite out of sight of each other. Under such circumstances the substitution of one light centre, however powerful, for every eight could only be done by leaving many spots in complete darkness. To give a usefully diffused light by means of arc lamps, their number would have to be considerably greater than ninety-two, or, in other words, the standard of street lighting would have to be raised, and for this the town was not prepared to pay.

Besides the systems for the supply of electricity which have been described there are other plans, two of which have special advantages, and should not be omitted from a Paper on this subject, although neither are at present in operation.

They are (1) the method of supplying a district by means of accumulators or storage batteries, charged by a current of high tension led direct to the batteries from the generating-station; and (2) the series system, in which all the lamps are strung in a continuous circuit, the whole current being utilized at various points successively, and not divided for the purpose of distribution into a number of parallel circuits, so as to supply different customers.

(1.) The Distribution with Secondary Batteries.

Mr. Lane Fox was the first to put forward a complete system of electrical supply on this plan (Fig. 6, p. 414).

The system is discussed by him as follows[1]:—

"The chief points of the system is the use of a generator in a central position, from one pole of which insulated conductors or mains are led to the several points where the electric energy is to be utilized, being branched and sub-branched as much as required, and thence back to the other pole of the generator by an uninsulated conductor, such as the gas or water pipes. At certain points, storage or secondary batteries are set up in connection, on one hand, with the mains, sub-mains, and branches, as the exigencies of the case may require, and on the other, with the return conductor.

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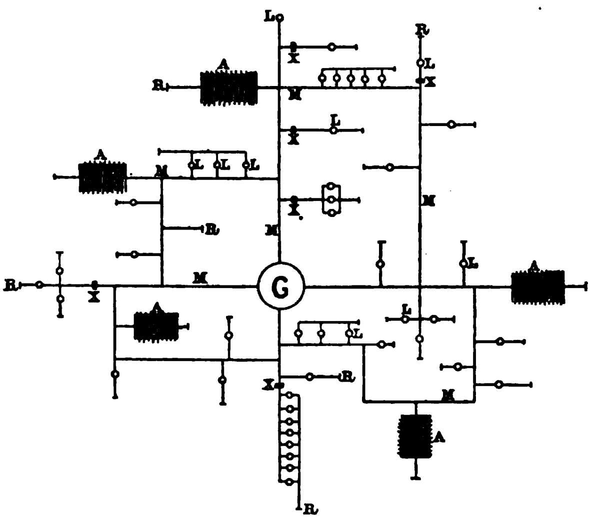
[1] Proceedings of Association of Municipal and Sanitary Engineers and Surveyors. Vol. ix.—1882-83, p. 159.

"The combination of generators, circuit and storage batteries is such, that when the current from the generators falls below the demands made on it from the various outlets to the mains at which its energy is utilized, the deficiency is made up from the storage batteries, which act in unison to supply the requisite quantity of energy. On the other hand, when the current from the generator exceeds in point of quantity the demands upon it at the various outlets, the excess goes to charge the storage batteries and to create a reserve to be called upon in case of need."

The objection to the system which prevented it being put in practical operation was the use of the earth as a return conductor. Besides the great danger of short-circuit, the gas- and the water-

Fig. 6.



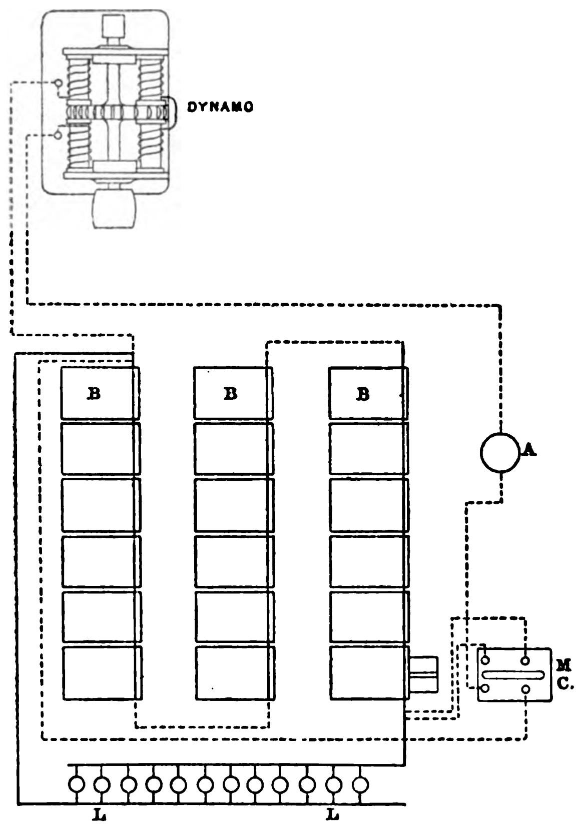
G Generating-station. A Accumulators (secondary batteries). R Returns.
M Mains or conductors. Lo Lamps. X Meters.

pipes, which are so thickly laid in most cities, would conduct the current and interrupt telegraphic and telephonic communication. The experiment of using storage batteries as reservoirs, from which a constant supply of electricity could be drawn as required, was tried on a considerable scale at Colchester, where a large installation was started in 1884, secondary batteries being placed in favourable positions, and charged by a high-tension current. The plan adopted is shown by Fig. 7.

The dynamos were two of the Brush type, each dynamo giving a current of 9·5 amperes, with an electro-motive force of 1,800 volts, when rotated at a speed of 700 revolutions per minute. They were driven by a semi-portable engine indicating 90 HP. The dynamos

were coupled in parallel or circuit for quantity, and excited by a small machine giving 10 amperes. The current was led some distance by a seven-strand 19 B. W. G. cable to the batteries, which were charged in series, the 60-volt lamps being placed in parallel on separate mains connected to the batteries. The danger of

FIG. 7.



A is a meter in charging circuit; B, the batteries or accumulators; L, lamps in parallel on low-pressure service main.

introducing a high-tension current of 1,800 volts into the houses was obviated by a rocking-switch worked automatically, so as to throw the batteries out of the charging-circuit. This operation was accomplished by means of a master cell (M C, Fig. 7), similar to the others, but fitted with an arrangement to collect the gas evolved, which extended a diaphragm attached to a make-and-

break arrangement which worked the rocking-switch. The Colchester installation did not turn out commercially successful, and has been abandoned; but the experiment has been valuable, and there is little doubt that, with simplification of details, a high-tension charging current could be led from a dynamo fixed in any convenient site where power is available; also in very crowded districts the batteries could be placed in cellars and be drawn from as reservoirs, so as to furnish a constant supply of electricity.

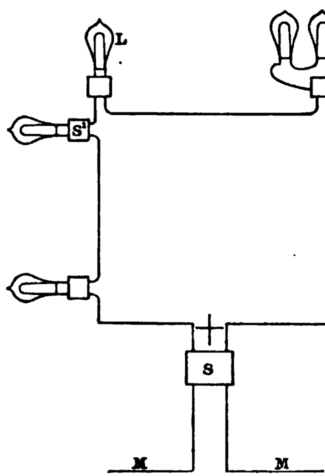
(2.) The Series System of Distribution.

This method dates back to the introduction of the incandescent light, and although a small current of high potential could be economically employed, the series system has never been installed on a commercial scale for incandescent lighting. In the United States the usual pressure for arc lighting is 2,000 volts, and it is not an uncommon occurrence to have forty arc lamps in series upon a line over 10 miles in length, carrying a current of 10 amperes. To economically use this high pressure for glow lamps in series, they must be of such design as to enable the whole of the current to be passed through them without injury. The filament of an ordinary high-resistance glow lamp would be immediately destroyed, so that low-resistance lamps, having a much larger sectional area, must be employed. The Bernstein or the Cruto lamp, which can be made to have a "hot" resistance of about 0·7 ohm, and require a current of 9·75 amperes, could be used, and the current might be economically brought from a great distance. Mr. Bernstein calculates that it would be possible to operate six thousand of these 7-volt lamps from twenty dynamos, each giving a current of 10 amperes at a potential of 2,000 volts, and still have a margin for loss of current in the leads. An economical feature of this scheme is the easy way in which power could be saved when only comparatively few lights were required; for instance, in the daytime all the circuits could be looped together and fed by one dynamo, and, as the number of lights increased, so other machines could be switched in by having an auxiliary bank of lamps as a resistance. From the central station twenty pairs of carefully insulated copper wires, say of No. 6 B. W. G., would lead to the houses; and as a good-sized ordinary house takes on an average twenty lights, the conductor would pass through fifteen houses before it returned to the station. It is in the house that the practical difficulty commences, as in this series system the circuit must never be opened, so that the switches and safety appliances must be such that, whatever happens, there must

remain some path for the current, otherwise all the lights on that particular circuit would be extinguished. Mr. Bernstein gives the designation of "short closed" if the current goes through the switch-lever, and "long closed" if the current is led through the lamps or other electrical devices.

Fig. 8 is a diagram of the lamps in any building. The street main M enters at the main switch S, and continues from switch to switch S^1 S^1, and returns to S before it leaves. It is necessary, to guard against any possible extinction, to construct all the switches so that it would be impossible to move the lever without a lamp

FIG. 8.



was lighted; and, should the lamp give out, an equivalent resistance must be automatically inserted. These details have been investigated by Mr. Alexander Bernstein,[1] who has designed a complete system for "series" lighting, and claims for it special economical advantages. It is, however, very doubtful if this plan can be recommended for adoption in private houses; but in public lighting, or in large establishments where an electrician could be kept to look after the fittings and the insulation of the conductors, there should be no more danger, in introducing the high-tension continuous current of 2,000 volts, than there is at present with the 100-volt alternating current, and the relative saving in weight of conductors would be an important item.

The Paper is illustrated by several diagrams, from which the Figs. in the text have been engraved.

[1] Journal of the Society of Telegraph-Engineers and Electricians, vol. xv. p. 161.

APPENDIX I.—PRINCIPAL ELECTRIC-

Name of Station.	Number of lights.		System employed.	Approximate length of longest main supply conductor in miles.	Main conductor overhead or underground.	Approximate area of distribution.
	Glow Lamps.	Arc Lamps.				
Grosvenor District Electrical Supply	3,000	None	High tension with Goulard Transformers primary 2,400 volts, secondary 100 volts, Siemens dynamos	9	Overhead	Very irregular district, a house is lighted 2 miles from the station
Brighton Electric-Light Company	875	27	High tension lamps in multiple series Brush Dynamos	11	Overhead	About 2 square miles
Victoria Lighting Station	1,500	None	Low tension lamps in parallel Crompton Dynamos		Partly Underground	The whole of the L. C. & D. Railway Station is lighted, the offices and printing works: also the signal-boxes and outside lights
Tilbury Docks Lighting Station	1,350 to be extended to 1,700	80 100	Crompton Dynamos 105 volt lamps	2	Overhead	300 acres
Paddington Electric Lighting	4,115 25C.P. lamps	98 3000 C.P.	E. M. F. 150 volts, Gordon Dynamos Swan lamps	3	Underground	67 acres
Kensington Court Electric Lighting Company	800 to be extended to 1,300	None	Crompton 105 volts low tension, constant supply by means of accumulators	¼	Underground	

LIGHTING STATIONS IN GREAT BRITAIN.

Number of Lights in one building.		Hours of Supply.	Charges.		Remarks.
Greatest.	Least.		By Meter.	By yearly fixed amount.	
300	16	8 A.M. to 12 P.M.	½d. per lamp per hour	£2 per annum per 16-candle-power lamp	
100	3	Dusk until daylight	Meter rent 21s. 8d. per annum	Glow lamps, 1s. per unit, or rather under ½d. per lamp per hour. Arc lamps 4s. per lamp per week including maintenance	If consumption does not exceed 100 units quarterly, 1s. 2d. per unit.
				The Swan United Company contract to light the station, &c., at a fixed sum per annum	This station was designed under a provisional order to supply 9,000 lamps.
		Dusk until daylight		The lighting is maintained by the Dock Company	The lighting comprises the whole of the dock property, including a large hotel, sheds, canteen and offices.
		Constant			The district between Paddington and Westbourne Park stations is lighted throughout.
		Constant	By meter and minimum charge of 10s. per light per annum	8d. per unit, equal to 0·56d. per 20-C.-P. lamp per hour, or 0·28d. per 10-C.-P. lamp. Shops taken at £2 per annum per 20-C.-P. lamp minimum of 10 lights	District embraces residences, shops, and public hall.

APPENDIX II.—PRINCIPAL ELECTRIC-

Name of Station.	Number of Lights.		System employed.	Approximate length of longest main supply conductor in miles.	Main conductor overhead or underground.	Approximate area of distribution.
	Incandescent or Glow Lamps.	Arc.				
Antwerp .	6,000	80	Gulcher Dynamos; Lane Fox lamp	½	Underground	1 square mile
Bergen .	3,000	70	..	..	..	..
Berlin . .	1,800	..	Edison lamps 110 volts	..	Underground	On the three-wire system
" . .	4,000	20	"	1½	"	
" . .	500	..	"	..	"	
" . .	6,000	26	"	..	"	
Breslau .	1,200	69	" "	..	Underground	..
Crefeld .	1,560	..	" "	..	"	..
Hamburg .	1,400	80	" "	..	"	..
Hernösand	..	70	Thomson Houston	..	Overhead	..
Halle . .	1,350	10	Edison	..	Underground	..
Hanover .	6,000	..	Do.	..	Do.	..
Lucerne .	300	..	Zipernowsky high-tension current with transformers	4	overhead	To be extended throughout Lucerne

LIGHTING STATIONS ON THE CONTINENT.

Number of Lights in one building.		Hours of Supply.	Charges.		Remarks.
Greatest.	Least.		By Meter.	By yearly fixed amount.	
300	10	Dusk until midnight	Meter	.. ..	Price equivalent to gas at 6s. per 1,000 cubic feet.
Streetlighting and public buildings		..	..	.. ..	..
These installations supply clubs, theatres, public buildings and street lighting		Constant service	..	6s. per year fixed charge, and ½d. per hour per 16-C.-P. lamp; arc lamps, 6d. and 7d. per hour, and 60s. yearly per light	Friedrich Street. Mauer Street.[1] Markgrafen Street. Schadou Street.
Railway station and mills		..	..	.. ..	..
Mills and factories		..	..	.. ..	..
Street lighting		Dusk until dawn	..	.. ..	..
..		..	..	.. ..	Yearly contract, which is less than former lighting by oil.
Stadt Theatre		..	..	.. ..	..
Shops and public buildings		..	By meter to subscribers for three years	0·42d. per 10-C.-P. lamp per hour; 0·5d. per 16-C.-P.	Not completed. 500 lamps now supplied by Zipernowsky system.
In hotels		Dusk until midnight	..	.. ..	Motive power, water

[1] Will be shortly extended to one thousand two hundred and fifty incandescent and one hundred arc lamps.

APPENDIX II.—PRINCIPAL ELECTRIC

Name of Station.	Number of Lights. Incandescent or Glow Lamps.	Number of Lights. Arc.	System employed.	Approximate length of longest main supply conductor in miles.	Main conductor overhead or underground.	Approximate area of distribution.
Milan . .	10,000	80[1]	Edison	$\frac{3}{4}$	underground	$1\frac{1}{2}$ square mile
	1,000	..	Zipernowsky	Do.	Do.	Theatre with 460 lamps in houses
Munich .	2,500	140	Edison	..	Do.	Two theatres
Rome . .	1,200	..	Zipernowsky	..	overhead	Hotels and shops
Rotterdam	1,000	..	Edison	..	underground	
Strassburg	1,000	62	Edison and Siemens	..	underground and overhead	Railway station and goods yards, 86 acres area
Stuttgart .	1,060	..	Do.	..	underground	Theatre
Schwerin .	2,390	..	Do.	..	Do.	Do.
Tivoli . .	1,000	6	Gaulard high-tension transformers	18	overhead	Principally street lighting
Tours . .	3,500	..	Do.	3	Do.	..
Temesvar .	760	..	Brush machines; Lane-Fox lamps	2	Do.	About 37 miles of streets
Vienna .	7,000	..	Crompton Low-tension dynamos with accumulators	$\frac{1}{2}$	underground	Opera house, theatre, and municipal buildings

[1] Will be shortly extended to ten thousand incandescent and one hundred arc lamps.

LIGHTING STATIONS ON THE CONTINENT—*continued.*

Number of Lights in one building.		Hours of Supply.	Charges.		Remarks.
Greatest.	Least.		By Meter.	By yearly fixed amount.	
2,600	3	Constant Do.	Arc and incandescent $\frac{1}{2}d.$ per ampere hour	Installation charge per lamp per 10 candles, 8*s.* „ 16 „ 28*s.* „ 32 „ 56*s.* Arc lamp £2 per annum rent	
..	..	Dusk until daylight	..	Net cost of lighting station, including 12 per cent. for interest and renewal — Arc lamps, $3\frac{3}{4}d.$ per hour; 16-C.-P. glow-lamps, 0·42*d.* per hour; 10-C.-P. glow-lamps, 0·32*d.* per hour; 8-C.-P. glow-lamps, 0·29*d.* per hour	Carried out by the railway company. The cost is estimated at one-third less than gas.
..	..	..	..	.. ..	Motive-power, water; yearly contract for street lighting.
..	..	..	..	Subscribers at 2*s.* 9*d.* per 16-C.-P. lamp per month	Three distributing stations at work, to be increased to ten.
Street lighting chiefly		Dusk until dawn	..	Street lighting, 1·5 kreutzer per 16-C.-P. lamp per hour Private consumers, 1·81 kreutzer	
..	..	..	..	By contract at a price about double gas	This installation is being put down by the Gas Company which lights the city.

(*Paper No. 2218.*)

"The Iron Skeleton of the Statue of Liberty on Bedloe's Island, New York Harbour."

By Theophilus Seyrig, M. Inst. C.E.

The recently completed statue on Bedloe's island, near New York, comprises three distinct parts:—First, the masonry pedestal; secondly, the wrought-iron skeleton; thirdly, the copper skin. Some few details concerning the second part, which more specially concerns the art of the engineer, may be of interest.

The skeleton which supports the outer envelope or skin of the statue, has approximately the shape of an iron viaduct-pier. It is composed of four principals, which stand on a base 16 feet long and 12 feet 6 inches in breadth. The section of these principals is that of a large L, each side of which is 2 feet in length. The plates are $\frac{7}{16}$ inch thick. The summit of the angle is strengthened by four angle-irons 4 inches by 4 inches by $\frac{9}{16}$ inch, and the edges of the plates are also bordered by angle-irons $3\frac{1}{2}$ inches by $3\frac{1}{2}$ inches by $\frac{7}{16}$ inch. The bracing of the principals is riveted to the plates, and consists of horizontal bars and of diagonals. All these bars are of similar section, being formed of two angle-irons riveted together so as to present a ⊥ shape. The size of the angles varies from 4 inches by 4 inches by $\frac{9}{16}$ inch to $3\frac{1}{2}$ inches by $3\frac{1}{2}$ inches by $\frac{7}{16}$ inch.

The lower end of each principal is widened out by gusset-plates, so as to enlarge the bearing-surface of the plate, which rests on the supporting beams. In the three external angles thus formed, the holding-down bolts are lodged. These bolts, $4\frac{3}{4}$ inches in diameter, were at first intended to penetrate a solid mass of masonry to the depth of 26 feet 3 inches, which was largely sufficient to prevent any possibility of overturning. Architectural motives, however, have led, on erection, to the modification of this part of the design, and the monumental base provided for the statue is in reality a hollow mass. The walls of this pedestal are about 8 feet 6 inches thick at their thinnest part; they are carefully built of granite with concrete backing, in which the fastening of the principals must needs take place.

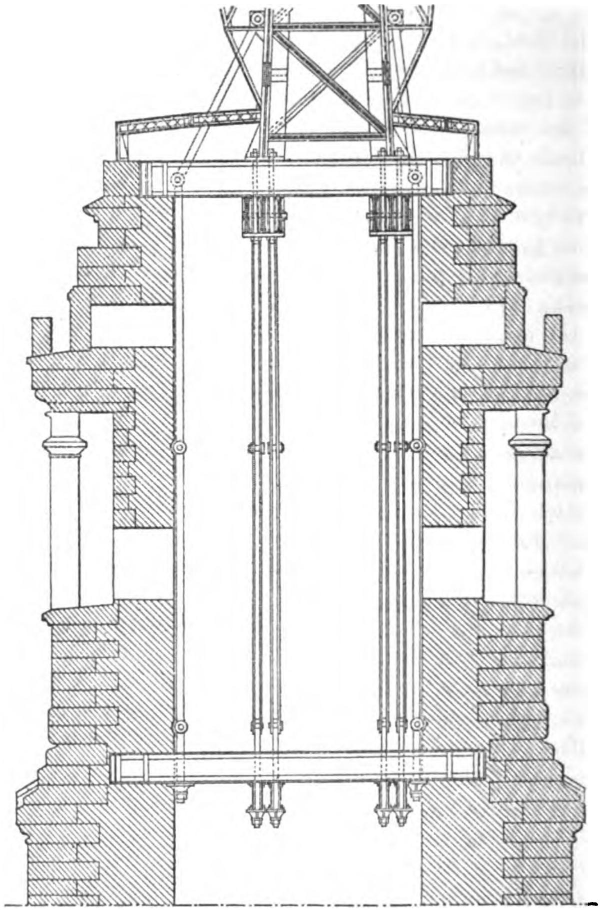
The shaft or hollow space above mentioned, being 27 feet square, the bases of the principals fall within it. The latter have therefore been supported by steel-plate girders, the first set of which are six in number, arranged in two groups of three, each batch supporting two principals. Below these is a second set of six at right angles with the first, and crossing them exactly beneath the principals. The three holding-down bolts of each principal are thus connected to one of each of the two sets of girders. These rest on the top of the masonry at either end. They are 4 feet 3 inches in depth, made of a $\frac{5}{8}$ inch web and four angles 5 inches by 4 inches.

Since tensions may possibly arise in the principals from the action of the wind on the statue, the girders had to be securely tied down to the masonry. This was done by means of ties fixed near the end of the girders, and attached about 60 feet lower down to a similar set of plate girders. The ties are made of steel eye-bars of the form in common use in America. They are placed close to the inner faces of the shaft, in sixteen pairs, each consisting of two bars 5 inches wide and 1 inch thick. To each set corresponds a pair of lower girders, 41 feet long and 3 feet deep, making altogether sixteen girders firmly embedded in concrete at their ends. All pins and screw-ends are $4\frac{1}{2}$ inches in diameter. At their top ends the eye-bars, although connected to the girders by stout pins, are prolonged obliquely so as to join the principals at points about 12 feet above the base, thereby giving additional stability.

The skeleton frame is 93 feet in height, and thus reaches to about the chin of the statue. It is divided into eight panels of very nearly the same size. At top it is 7 feet 4 inches by 5 feet 11 inches. The two top panels, which together are 21 feet 4 inches in height, serve as abutment for a lateral girder which reaches into the uplifted arm of the statue, and as far as the torch which is borne by it. This girder or strut, although curved to requirement, is built up in lattice-work. The four booms are made of angle-irons, opposed at their corners thus $_{\urcorner}{}^{\llcorner}$, so as to attain the greatest possible stiffness in compression members. The diagonals are made of single angle-irons, fixed to the booms by means of gusset plates. They are single in every case and not crossed as usual.

Around the central pier is a complete skeleton frame designed to approach in every part as near as possible to the copper skin. This frame is simply built up of light angle-irons with diagonals and horizontals corresponding to those of the central part. On this frame are bolted flat bars, which accurately follow the contours of the skin, and to which the copper is fixed. The lower part of the pier is also surrounded by a platform on which the statue appears

to stand. Eight lattice girders go from the principals to the masonry; they support other similar girders upon which the copper skin for the base is spread out.



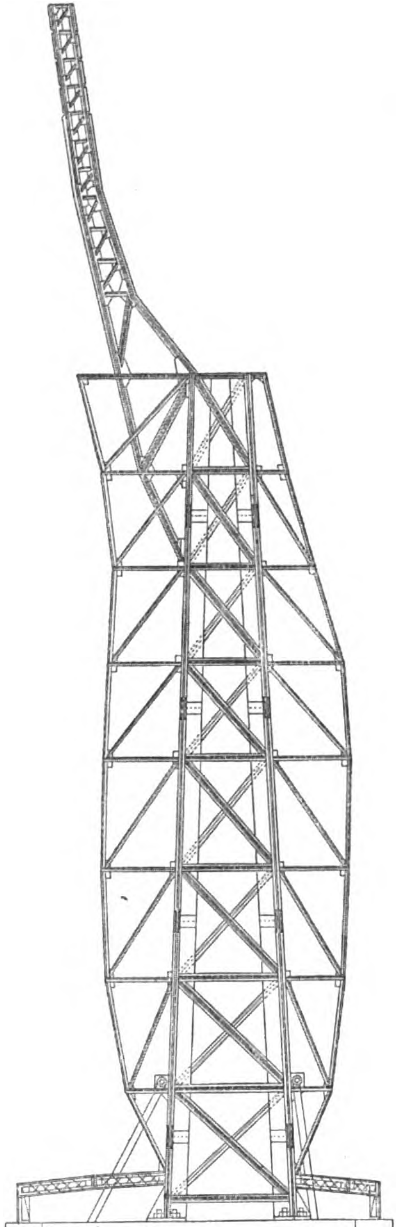
Scale $\frac{1}{110}$.

VERTICAL SECTION OF THE PEDESTAL.

The copper plates of the statue are 0·1 inch thick. They have riveted joints, the overlap being made so as to give a flush surface, and no rivet-heads are visible, these are countersunk on the outside. The skin is fixed to the skeleton by means of cop-

per bands 2 inches wide by $\frac{1}{3}$ inch thick, which are bent round the iron bars. They are thus allowed freely to move by expansion. To prevent clattering, and also because chemical action caused by electrical currents was feared, the iron bars have been first thickly painted with shellac and then enveloped in asbestos fibre. Should electrical currents really set up, this precaution may eventually be found to be of but little use.

The danger arising from atmospheric electricity is certainly not to be neglected, and the effects of lightning, more especially upon the foundations, might be very serious. To guard against this, lightning-conductors have been disposed inside the statue. They consist of five copper rods, each $\frac{3}{4}$ inch in diameter, leading into wells sunk at the base of the building. The rods dip into the water several feet. They are carried up through the interior of the metallic structure by lengths of 30 feet, made continuous by screwing into sockets of the same metal. The last piece is joined to the skin of the statue by soldering over a length of about 12 feet.



Scale $\frac{1}{150}$.

ELEVATION OF THE SKELETON.

The calculation of the sections in the ironwork was made by the ordinary process.

The weight to be carried by the skeleton has been estimated at about 120 tons for the ironwork, and 80 tons of copper skin. The pressure of the wind upon the projected surface of the statue has been calculated, but it is clear that such an estimate is more or less empirical. The wind-pressure has been assumed equal to 55 lbs. per square foot on the projected vertical surface. The bending-moments and transverse-strains have been determined on this assumption, the structure being considered as a vertical girder built in at its base. The torsional effects which will arise from the non-symmetrical form of the statue seem, however, to have been neglected, although it appears that they may very notably increase the calculated strains. The figures obtained show that in no part the strains on the metal exceed 5 tons per square inch. They range, however, in the same elements between 5 tons in compression to 3 tons in compression, which may appear rather heavy, taking into account the very sudden efforts which the wind may occasion, and also the greater effect caused by the rythmic repetition of these efforts, when oscillation may ensue.

The use of the statue as a lighthouse was decided upon after some hesitation. Nothing had been originally provided for this purpose, and during erection the torch was prepared by cutting openings in the skin, thirty-six in number and 16 inches in diameter. These are glazed with plate glass. Within the torch, opposite these windows, are placed eight electric lights of 6,000 candle-power each, which shine in every direction, and can be seen from the open sea beyond the intervening island. The motive power for the lights consists of dynamos placed in a small building adjoining the pedestal, on one of the old bastions which surround the pedestal.

(*Paper No. 2228.*)

"Siphon-Outlet for a Low-Sewer District, Norfolk, Virginia, U.S.A."

By George E. Waring, jun., M. Inst. C.E.

Early in the year 1882, the sewerage of the city of Norfolk, Virginia (U.S.A.), was begun according to plans prepared by the Author and under his direction. One of the sections to be drained was, according to the original design, to be connected with the pumping-well by a long line of 18-inch pipe sewer through Brewer Street, laid, at its deepest part, 19 feet below the surface, and for a long distance to a depth of more than 16 feet.

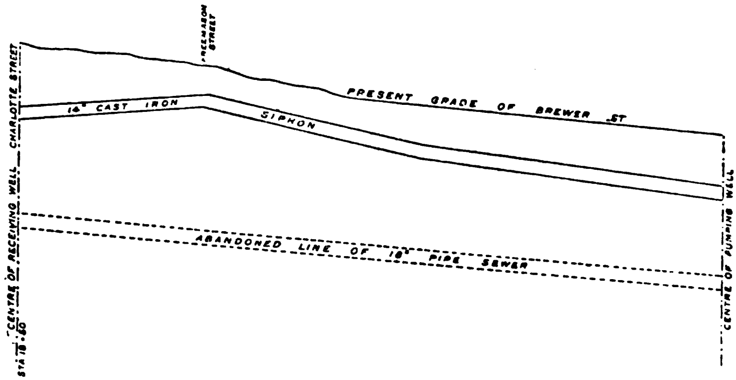
The contractor succeeded in laying this sewer as far as Charlotte Street, 1,850 feet from the pumping-well. The work had for a great length been extremely difficult and hazardous, on account of a troublesome quicksand encountered after descending nearly to tide-level, at this point about 10 feet below the surface. Thus far, the street had been bordered only by houses of moderate size and weight. Below Charlotte Street there were several large buildings, including one very large brick Masonic Temple, which would obviously be endangered by the running of the ground were the attempt made to carry the sewer past it at full depth. There was no other course through which this outlet sewer might be taken without equally serious difficulties; it became necessary, therefore, to devise special means for passing these large buildings without deep excavation.

On the resumption of work in March, 1884, the Author submitted a plan for passing by this obstruction with a siphon, which was carried into execution. The work was completed in May, 1885, and a satisfactory and effective outlet was thus afforded for this important drainage district.

The details of construction are shown in Fig. 1 and Figs. 2. Fig. 1 is a profile of the line from the centre of Charlotte Street, along Brewer Street, to the pumping-well. The lower lines are the grade lines of the 18-inch pipe sewer provided for in the original plan. The surface line is the surface of Brewer Street at its present, completed, grade. The upper lines show the horizontal course of a 14-inch cast-iron pipe constituting the outlet siphon.

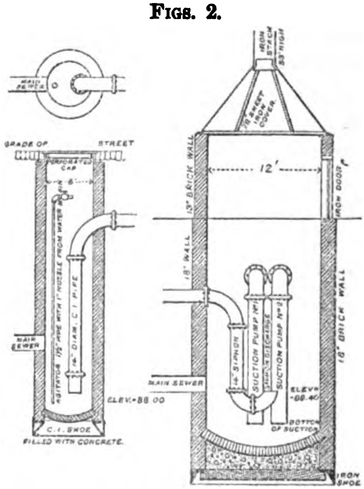
At Charlotte Street it is 7 feet 8 inches below the surface. At Freemason Street, the apex of the siphon is 1 foot 6 inches higher

Fig. 1.



than at its starting point. It is 4 feet 2 inches below the surface, and at the lower end of Brewer Street it is 6 feet 8 inches below the surface. At this depth, there was no obstacle to easy and rapid work. The fall of the siphon from the apex to the lower end of Brewer Street is about 9 feet.

Figs. 2.



Scale $\frac{1}{110}$.

Figs. 2 show sections and relative elevations of the receiving well, at Charlotte Street, and of the pumping-well at the lower end of Brewer Street; also the arrangement and relative elevation

of the intake and discharge of the siphon, and of the suction-pipes of the sewage-pumps.

The lower end of the siphon, in the pumping-well, is furnished with a return bend of which the outlet, opening upward, is 5 inches higher than the intake at the upper end of the siphon. Therefore, as no flow can take place below the mouth of the outlet, the intake must at all times be submerged at least 5 inches, and both ends of the siphon be permanently sealed. At the apex of the siphon, there is an elevated chamber, with a shut-off gate and check-valve, connected by a 2-inch galvanized pipe to an air-pump at the pumping-station.

The siphon was charged by allowing both wells to fill to a sufficient height, and by working the air-pump until it drew water. From that time until the present, the siphon has acted constantly, and without difficulty or obstruction of any sort. This pump is worked for a few minutes every day.

In a letter to the Author, dated the 28th of August, 1886, Mr. W. T. Brooke, the City Engineer of Norfolk, writes:—

"The working of the siphon has been all that could be expected. It would be sufficient to say that it has never ceased to work since it was charged at the beginning, but it has stood even a more severe test than this. Last winter a water-main burst in Brewer Street about 100 feet beyond the upper well. There was a broken 18-inch pipe just under the point where the main gave way, and in consequence, before the leak, which occurred at night, could be stopped, at least thirty or more cartloads of sand were washed into the upper 5-foot discharging well. It all passed over into the lower well, and neither then, nor at any other time since the siphon was started, have I had to remove a shovelful of anything from the upper well."

The Paper is accompanied by several diagrams, from which the Figs. in the text have been engraved.

OBITUARY.

JOHN BRANDT, the youngest son of the Rev. Francis Brandt, formerly rector of Aldford, near Chester, was born in 1838, and was educated at Cheltenham College. At the age of fifteen he was apprenticed for five years to Messrs. James Nasmyth and Co., of Patricroft, Manchester. On the completion of his articles at the end of 1857, he served for a year in the locomotive works and the drawing office of the Manchester, Sheffield, and Lincolnshire Railway at Gorton; he was also, for a short time, in the works of Sir William (then Mr.) Fairbairn. His mechanical training was thus exceptionally complete; he was also a good surveyor, and was otherwise well versed in the manifold studies essential for the practice of civil engineering. At the beginning of 1859 it had been arranged that he should go to India as an assistant to Mr. John Brunton, M. Inst. C.E., who was then laying out the Scinde Railway; but circumstances prevented the fulfilment of this intention. He was then appointed to the engineering staff of Mr. Henry Robertson, M. Inst. C.E., afterwards M.P. for Shrewsbury, and at that time largely occupied in the construction of railways. The association thus commenced lasted nearly through life, the whole of Mr. Brandt's professional career having been identified with the construction of railways in the district between Liverpool and Chester, and in Wales. Of these the most important were: the extension of the London and North-Western line from Craven Arms to Llandovery; and the extension of the Great Western through the Vale of Llangollen and Bala to the important slate district of Blaenau Festiniog. He was also engaged in promoting lines for the same companies in the Wrexham and Brymbo districts. Having been associated with Mr. Robertson for a quarter of a century, Mr. Brandt was, in October 1884, appointed Engineer of the Seacombe, Hoylake, and Deeside Railway, acting also as Resident Engineer of the Wirral Railway, which two companies had obtained powers to construct lines joining those of the Manchester, Sheffield, and Lincolnshire Railway at Connah's Quay. Extensions to New Brighton and Seacombe in a northerly direction, joining a branch of the Mersey Railway Company at Birkenhead, were also designed, and when completed will afford a continuous new route from the collieries of North Wales to Birkenhead and Liverpool.

Mr. Brandt was also Resident Engineer of the new bridge over the Severn at Shrewsbury, and of the road in connection with it. He was elected a Member of the Institution on the 7th of March, 1876, and died on the 21st of October, 1886.

WALTON WHITE EVANS died on the 28th of November, 1886, in his seventieth year. Apart from his having been one of the best known engineers in the United States, his career is of interest as being that of a typical American of the highest class —cultured, chivalrous, and refined, plentifully endowed with shrewdness and mother-wit, while of a most generous and honourable character.

He was a grandson, on the maternal side, of General Anthony White, of revolutionary fame, and through his mother was connected with the Van Rensselaer family of New York. He was born at New Brunswick, in the State of New Jersey, on the 31st of October, 1817; and was educated at the Polytechnic Institute of Troy, New York, of which celebrated institution he was with one exception, at his death, the oldest graduate. He took his degree in 1836, and having chosen engineering as a profession, immediately became Assistant Engineer on the enlargement of the Erie Canal, which was being carried out as a State enterprise. On the completion of this work in 1843, he travelled for some months, examining different public works and so enlarging his experience. Shortly afterwards his association began with a series of railroad works, which have made his name well known, not only all over the American continent, but also in Australia and in New Zealand. He was first engaged as Resident Engineer on the extension of the Harlem railway to Albany, remaining in that service till 1849. The following year he accompanied Mr. Allan Campbell to Chili as an Assistant, to take charge of the surveys and construction of the Copiapo Railway, and on the return of Mr. Campbell to the United States a year later, he became Chief Engineer. This visit to Chili was the beginning of a connection with the South American republics, which lasted through Mr. Evans's life. He was engaged on the Copiapo line until 1853, when he left in order to make an extensive tour in Europe. He visited in succession England, France, and Germany, and was engaged for the better part of a year in visiting the public works of those countries. He had, in May, 1853, while in Chili, accepted the position of Chief Engineer of the Arica and Tacna Railway in

Peru, and a year later he started for the site of the proposed line. In constructing this railway, the first in Peru, Mr. Evans had to contend with difficulties of no ordinary character, chief among them, as he pithily describes it, being "fever and revolution." But he managed to surmount them all, and the line was successfully completed in 1856. He also during this time acted as Engineer and "umpire" for the first extension of the Copiapo Railway, from Copiapo to Pabellon, being at the same time offered the position of Chief Engineer of the Santiago and Valparaiso Railway, which he, however, declined.

Leaving Peru in 1856, Mr. Evans visited many of the public works in the United States, but returned to South America in November of the same year to take charge as Engineer of the surveys and construction of the Southern Railway of Chili, a work chiefly owned by the State. He remained on this line until its completion to Rancagua, in 1859. During this time he was also the Chief Engineer and umpire in the construction of the Copiapo Extension Railway from Pabellon to Chanarcillo, which passed over a summit of 4,467 feet above tide, at that time far the highest railway summit in the world. Returning to the United States, in 1860, he spent a year in recruiting his health, which had become impaired by yellow fever, by the anxiety for the works occasioned by three revolutions, and by the taking of the town he lived in three times by storm, to say nothing of the effects of labour and exposure in a tropical climate and the deadening influences of life in a desert. In 1862 he was appointed Engineer to the Commission for the Harbour and Frontier Defences of the State of New York. This position he occupied until the Commission was dissolved in 1865. In 1866 he was appointed by the Secretary of the Interior to assist in establishing a system of standards for railways to the Pacific, in which the United States had an interest. For the last twenty years of his life Mr. Evans resided near New York, acting as Advising and Inspecting Engineer on the Arequipa Railway, the Lima and Huacho Railway, the Eten Railway, the Pisco and Yca Railway, and the Arica and Tacna Railway in Peru; and now, for the Peruvian Government, in the construction of the two Transandine Railways—one running from Lima to Oroya, the other from Arequipa to Pisco, both passing over summits nearly 15,000 feet high. He also acted for the Chilian Government in the construction of the Chillan Concepcion and Talcahuana Railway; also for the Southern Railway and the Tongoi Railway of Chili; for the Boca Railway in Buenos Ayres; and for the Central Argentine Railway.

Besides his railway enterprises, Mr. Evans designed and superintended the erection of many of the Public edifices and private mansions which adorn the capitals of the South American republics. In connection with building, it may be mentioned that he was an enthusiastic admirer of the masonry of the ancient Egyptians.[1]

He also devoted much of his time to the consideration of canal-construction, and wrote a series of articles on interoceanic communication, which attracted great attention both in the States and in Europe. He favoured the San Blas route for a ship-canal through central America, and was of opinion that the Panama route, chosen by Sir F. de Lesseps, is not feasible. He was an indefatigable student, never wearying in the study of the problems which presented themselves in the carrying out of novel and previously untried enterprises, and elucidating with the accuracy of a draughtsman and the clearness of an apt writer the difficulties presented, and overcome in his experiments. He was a consistent and persistent advocate of American ideas and methods in engineering matters, and to him the introduction and use of American rolling stock and machinery in South America and in Australia was largely due. He wrote several pamphlets under the signature of "Quid rides," in most of which may be traced his conviction that the United States as a country is fast achieving commercial, agricultural, and manufacturing supremacy; and though there is much to which an Englishman might take exception, there is no trace of unfairness, or of a disposition to "hit below the belt."

Mr. Evans was elected a Member of the Institution on the 6th

[1] In a letter referring to this subject he says, "I forget if I ever told you of my seeing there, in the Temple of the Sphinx (the oldest structure known to man), the evidence that over five thousand years ago, there were masons and stonecutters in Egypt, that had such marvellous skill of hand in cutting and laying up stone, that no man of the present day by any known method or tools can repeat it. Think of taking blocks of Red Sea granite (syenite) 20 feet long and 5 feet square, and cutting them so fine that when one is laid on the other, the joint is barely visible by a faint line, and in such places where the tooth of time has crumbled away the surface after five thousand years of exposure, as is the case in some spots as big as one's head, there the joint is invisible. Look around you for the finest joint in the best made cabinet of wood, and then think that the ancient Egyptians could make similar joints in stone 20 feet long, and work every joint in a large building the same; and then place the line of the building in the line of the meridian, so close that its azimuthal error will not be as great as the index-error in one of Troughton's 12-inch instruments, between the first and second 180° of its circle!"

of December, 1870. When in Europe he always made a point of calling at Great George Street, and if his visits occurred during the Society's session, he was an assiduous attendant at the meetings. The association was one of mutual advantage, and by the officers of the Institution Mr. Evans will be long remembered as a thorough gentleman and one of the most charming of men.

ARTHUR WILLIAM FORDE, a son of the Rev. Arthur Brownlow Forde, of Maghull, Lancashire, and county Down, Ireland, was born on the 12th of July, 1821. At the age of fifteen he was articled for five years to the late Mr. Godwin, M. Inst. C.E., the Engineer and General Manager of the Ulster Railway. From 1840 to 1843 he was in the employment of Mr. Dargan, the well-known Irish railway contractor, engaged on the extension of the Ulster Railway from Lisburn to Portadown, and on the Belfast Waterworks. He then re-entered the service of the Ulster Railway Company, and became Mr. Godwin's chief-assistant and Resident Engineer of the extension of the line from Portadown to Armagh; also on the Newry, Warrenpoint, and Rostrevor, the Newry and Enniskillen, and the Belfast and County Down railways; and he likewise assisted as General Manager. In 1849 Mr. Forde became Chief Engineer to the Londonderry and Enniskillen Railway, and completed the line into Londonderry, and was then appointed General Manager, in addition to his duties as Chief Engineer. He retained this position until 1855. In the latter year he was appointed Chief Engineer of the Bombay, Baroda, and Central India Railway, and henceforward India was his home.

Mr. Forde constructed the Taptee Bridge, and was the first engineer in India to employ the Warren girders in bridge construction, as he had already done in Ireland. From 1860 to 1862 he was engaged in constructing 20 miles of a railway of 2 feet 6 inches gauge for the Gackwar of Baroda, and promoted a company in London for branch railways in India, obtaining favourable concessions from the supreme government. Mr. Forde was by some credited with being an out-and-out advocate of the narrow-gauge. This is not altogether correct. He was in favour of the narrow-gauge system, but only where it would have been too expensive to employ the broad gauge, and he was never an advocate for break of gauge.[1] He was a conscientious labourer

[1] In connection with this subject he delivered a lecture before the Sassoon Mechanics' Institute, Bombay, entitled, "Railway Extensions in India, with

and did most of his work, even as to details, with his own hands. He left the employ of the Bombay, Baroda, and Central India Railway in 1860, and went into private practice up country. In 1864 he settled and practised as an engineer in Bombay with marked ability and success.

Mr. Forde began the work undertaken by the Frere Land Reclamation, and was for some years connected with the joint-stock company bearing that name. He also designed and built the Sassoon Dock, the first wet dock in Bombay. He reclaimed a large tract of land near Nowsaree, covering about 7,000 acres, which was named the Seaforde Land Reclamation, after his family seat in County Down, Ireland. A considerable portion of this land has already been brought into cultivation. In September, 1878, Mr. Forde was appointed Consulting Engineer to the Bombay Municipality for Drainage and Waterworks, and held the appointment to the time of his death. In December 1878 he made a comprehensive report on the general question of the new drainage scheme, and from time to time he was consulted by the municipal authorities in all matters of importance relating to drainage and waterworks, as well as in other matters. On the retirement of Mr. Francis Mathew in 1882, Mr. Forde was elected President of the Sassoon Mechanics' Institute, in which capacity he worked assiduously up to the time of his death in promoting its interests. He was a lover of art, and a skilful artist. His productions were exhibited every year at the Western India Fine Arts Exhibition; and in 1885 he carried away the prize for the best oil-painting. He also took a great interest in photography, and was lately elected President of the new Photographic Society of Bombay. He was a director of several local joint-stock companies, a Justice of the Peace, and a Dean of the Bombay University in Civil Engineering.

Mr. Forde was elected a Member of the Institution on the 4th of February, 1862. He died in Bombay on the 25th of October, 1886.

CHARLES FREDERIC GREEN, born on the 9th of December, 1845, was the second son of the late Abraham Green, of Essendon, Herts. He was educated at the Bedford Public School, where he early showed remarkable talent for science and mathematics. In a

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special reference to the export of wheat," which was afterwards published as a pamphlet. Tract. 8vo., Bombay, 1884. [Inst. C.E. Tracts. 8vo., vol. 393.]

letter written by the head master, the following reference was made to young Green: "I have rarely seen good natural talent combined with such indomitable energy and perseverance." Immediately upon leaving the above school he was placed by his guardians under Mr. C. H. Gough, then Resident Engineer on the Mid-Sussex Railway, who also bore testimony to his ability and integrity. After two years' pupilage he became assistant to Mr. R. Jacomb Hood, M. Inst. C.E., who placed him as Resident Engineer on the Lewes and Uckfield Railway. Upon leaving he commenced practice on his own account at Hertford, and, while there, carried out sea-defences both at Newhaven and at Bognor. At the latter place he won his first laurels, his plan obtaining the premium among forty-two competitors, and he was afterwards asked to carry out the work. At the age of twenty-six he passed the examination for County Surveyorships (Ireland), and was one hundred and twenty marks above the second competitor. He was then appointed County Surveyor to the East Riding of Cork, but did not remain two years, as he went up for another competitive examination for principal Assistant Engineer, Board of Works (Ireland), when he obtained five hundred marks more than the second man.

In the last twelve years of his life he acted as principal Assistant Engineer under Mr. Robert Manning, M. Inst. C.E., and was engaged in a number of duties of very varied character, such as works connected with harbours, inland navigation, bridges, arterial drainage, roads, &c. "It is," Mr. Manning says of him, "my melancholy duty to express my grateful acknowledgment of the able and willing assistance which I received from Mr. Green on all occasions, and to bear my testimony to the invariable kindness and consideration with which he treated every one with whom he came in contact, and which earned for him the respect, esteem, and friendship of all who knew him. His early death has been a great loss to the public service, and especially to me, and I deeply feel the sudden termination of so many years of intimacy with him."

He died on the 26th of September, 1886, at Stillorgan, county Dublin. He was a man of singular piety, and although possessed of great intellectual powers, was simple and gentle in character. As husband and father few could equal him, and it is in the home he has left that his memory will be most revered and cherished.

Mr. Green was elected a Member of the Institution on the 17th of January, 1877.

EDWARD WILLIAMS, son of Taliesin Williams, a schoolmaster of Merthyr Tydfil, Glamorganshire, and grandson of another Edward Williams, well known throughout Wales as Iolo Morganwg, was born on the 10th of February, 1826, and died at Cleveland Lodge, Middlesbrough, on the 9th of June, 1886. Iolo Morganwg was by trade a stonemason, as his father had been before him, but being of a very studious, as well as restless disposition, he spent most of his life wandering over South Wales, and backwards and forwards between there and London—always on foot—publishing poems in English and Welsh; attending Eisteddfodan; incurring the hostility of the English Government for his radicalism and his correspondence with the French Revolutionists; acquiring a variety of languages and other learning, but especially in gleaning every scrap of Welsh tradition and literature. Taliesin Williams also learned the trade of a mason, and further distinguished himself as an antiquary and bard. In his school—one of the best known of those days in South Wales—was educated his son Edward, along with several others who afterwards achieved distinction. Helping his father from an early age, both in and out of school, he had, as he himself once said, "but little childhood." At one time a nomination was offered which would have taken him to Jesus College, Oxford, and in all probability ended, as he always supposed, in his taking holy orders; but this was not accepted. He had always felt a strong inclination towards the iron trade of the district, and at the age of sixteen he entered the Dowlais Iron Company's service, the then general manager of Dowlais, Mr. Thomas Evans, having offered his father to give him "something to do." When he went to the office, the General Manager was engaged. He waited hour after hour; at last the General Manager came out and saw the lad he had quite forgotten; whereupon, taking him into the general office, he called to the head of it: "Here, Harrison; give this young fellow something to do;" shut the door, and was gone. So the boy was started; but having once got grip, he never let go. His first introduction to the out-door work came by writing reports for one of the staff who was illiterate. In the year 1845, being still under twenty years, he was chosen to look after the Company's shipping-matters at Cardiff. Dowlais had been a rough school, where none but those who had plenty of energy could live; and Cardiff was by no means a bed of roses. A small place with rapidly growing shipping, all the labour at the boats was claimed as an hereditary monopoly by a certain class of men, who demanded exorbitant pay, and even then would not do the necessary work: he engaged outsiders, and thereby

incurred their hatred. One night, going home to his lodgings (his way was a lonely one by the waterside), he observed, before he was clear of the streets, that some of his enemies were skulking along and dogging his steps. He turned back, and slept that night at a friend's lodgings, thereby in all probability saving his life. After three years in Cardiff, he insisted upon returning to Dowlais, even against the wish of the Company. His father died about this time, 1847, and leaving his family as ill provided for as a student and schoolmaster usually does, left a heavy burden upon his eldest son. Fighting against this, and against endless disappointments of his just hopes at Dowlais, he became at length, in 1855, forge and mill manager. This was when the general managership became vacant, and passed to the late William Menelaus, his senior by several years, who had previously been engineer; but Edward Williams took the second place, and bore thenceforward no small part with his friend in the management and development of the works. He was thoroughly master of every detail of wrought-iron making as then understood, and even in later years would take the tongs and show an obstinate workman exactly how a rail should be rolled; but at the same time he was ready for new ideas, and often carried out experiments upon his own initiative and authority. One evening in 1856, reading, as he always did, *The Times*, he found that a Mr. Bessemer, in a Paper before the British Association, at Cheltenham, had declared that by blowing cold air into molten iron, it was possible, without any fuel, to make it hotter and produce steel. Forthwith he put up a little furnace, expecting to prove the falseness of this. To his surprise, the iron really became hotter, instead of growing solid. He had no notion when to stop blowing; but when at length, the stuff was rolled into a bar, with wonderful readiness to seize a great result, he turned to a leading hand beside him and said: "Tom, puddling's done!"—all this within some three or four days of the reading of the Paper. The bar, however, when cold proved as brittle as earthenware, and piling and annealing, &c., &c., made it no better. Dowlais took up the Bessemer process, and Edward Williams worked hard to bring it to a practical result. After Sir Henry Bessemer, he was the first who made Bessemer steel; and, in 1858, he rolled at Dowlais, from ingots supplied by the inventor, the first rails ever made of that material. Only a few weeks before his death, his efforts in this direction were recognized by the presentation to him of the Iron and Steel Institute's Bessemer Medal for 1886.

In 1864 he left Dowlais. From practical iron-making he went to manage the commercial part of the firm's business, as head of

their London house of Guest and Co. In this new line, his ability and success were as conspicuous as they had always been in the old; but in little more than twelve months he accepted the post of General Manager to the new limited company which had just taken over the vast concerns of Messrs. Bolckow and Vaughan. Henceforward he lived in Middlesbrough. He was now thirty-nine years old, and had from the first perhaps nine thousand men under him, with charge of collieries, mines, blast-furnaces, mills, &c., and not only were the various undertakings of the company remodelled and modernized by him, but they constantly grew. New mines, new collieries, new furnaces; a Bessemer steelworks at Gorton, near Manchester, were among the additions, and just as he was about to commence, in lieu of the last, a steelworks at Eston, he resigned his position. The ten years and a half of his management began with the commercial gloom of 1866, but they were wonderful years of prosperity for the whole trade, and scarcely for any firm so much as for Bolckow, Vaughan and Co. He controlled its widespread concerns with as much success as he had achieved in a narrower sphere. One of his first tasks was to fight the terrible twenty weeks' strike, and lock-out of 1866, but there never was another of anything like so great moment in his time. He was an incomparable manager of men; they found him stern and hot tempered, but always just, kind-hearted and merciful.

Mr. Williams, in the year 1871, with the late Mr. Menelaus, Sir W. T. Lewis and others, purchased the Forest Furnaces at Pontypridd, and subsequently, in connection with other influential persons connected with the iron and steel trades, acquired the Tredegar Iron Works, both of which establishments were entirely remodelled and successfully carried on for iron- and steel-making. From the beginning of 1876, he acted as adviser to many undertakings, and in the year 1879 purchased the Linthorpe Blast Furnaces at Middlesbrough, which he carried on with great energy up to the time of his death.

He had been the first to use waste heat from coke ovens in burning bricks, &c.; he had experimented considerably with Mr. Menelaus in mechanical puddling, and under his supervision the early machines of Tooth, Walker, and others were thoroughly tested at Dowlais, whilst later he was one of the Committee appointed by the Iron and Steel Institute to investigate the whole subject. He was one of the earliest advocates in this country of taking the molten iron from the blast-furnace to the converter. His last great work was designing the Cyfarthfa Steelworks, and superintending their erection and starting. The old

Cyfarthfa wrought-iron works were admittedly unsurpassed in their day, and it is believed the same may now be said—not in respect of size, but so far as convenience of arrangement and excellence of plant are concerned—of the steelworks which occupy their site. In spite of sadly-failing health he stuck to this task, and saw it completed and put to the test of a year's working. Others would have given up under a small part of the physical suffering which he unfortunately disregarded.

As a young man he was Secretary to the South Wales Institution of Engineers, of which, indeed, he was one of the founders. In 1881, he renewed his more intimate connection with that Society on being elected its President for the twenty-fifth year of its existence. None were more prominent than he among those who in 1869 organized the Iron and Steel Institute. He was from the first a Member of the Council, and succeeded the late Sir William Siemens as President in 1879–81. He was elected a Member of this Institution on the 19th of May, 1868, and was connected with many other technical and scientific societies. His Papers "On the Manufacture of Rails," read before the Iron and Steel Institute at Middlesbrough, when it held its first provincial meeting in 1870, on the Progress of Iron and Steel Making from 1869–79, when he first sat as President of the same society, and his inaugural address as President of the South Wales Institution of Engineers, all contain matter very valuable at the time and likely to remain so in the literature of iron and steel.

He several times acted as arbitrator in wages disputes, and had always a generous sympathy with the aspirations of the labouring classes. Nothing irritated him more than to hear them decried "by a fellow who looked as if he had just come out of a bandbox."

His energy and interest were by no means confined to his business. He inherited a large part of the family inclination to literature, and was a most admirable public speaker. He took an active part in municipal affairs and in politics.

His quick temper occasionally led him into saying and doing things none regretted more than he did himself. His sense of justice was so keen, that on the spur of the moment he may have given utterance to words that sometimes vexed, but he never lost a friend and never made an enemy. His quiet unostentatious but real charity was great, and under his apparent roughness he hid a most tender, loving heart. His good sound advice to young people commencing their career, was often accompanied by liberal assistance of another kind, and his loss was deeply deplored by all who knew him.

THOMAS CHARLES ELLIS was born at Cowley, Middlesex, on the 11th of March, 1847, being a younger son of Mr. Thomas Ellis, of Uxbridge. He was educated at Eastbourne School, and in January, 1865, was articled for five years to Messrs. McClean and Stileman. On the completion of his pupilage he was appointed by the same firm Resident Engineer during the construction of the Keighley Waterworks, from 1870 to 1877; and was afterwards employed by them in various capacities until 1881. In the latter year he was engaged by Mr. Edward Filliter, M. Inst. C.E., as Resident Assistant Engineer upon the new waterworks for Wakefield, and superintended the construction of the large storage-reservoir at Ringstone and Ardsley, the Moss Moor Catchwater (an open conduit on the moors 4½ miles long), and the Spa Clough dam at the head thereof; also the laying of 2½ miles of gravitation main from Ringstone to Wakefield. In March, 1886, Mr. Ellis was from ill-health compelled to relinquish his duties at Ringstone, hoping, after a period of rest, to resume his appointment, but suffering a relapse he died on the 1st of October, 1886.

Mr. Ellis was a most obliging, industrious, and trustworthy man, taking great interest in every class of work intrusted to his care, and earning the respect and goodwill not only of his employers but of all those with whom he was associated. He was elected an Associate Member of the Institution on the 6th of May, 1873.

GEORGE HOLLAND ERSKINE was the eldest son of the late Captain David Holland Erskine, of the 92nd Gordon Highlanders. He was born on the 19th of December, 1858, at Madeira, where his father was at the time British Consul. In 1878 he was articled to Mr. William Bell, M. Inst. C.E., under whom he was employed during the two following years on the Neath Harbour and Dock works. In 1881 he was engaged by Messrs. Sir John Hawkshaw, Son, and Hayter, and was by them sent out to Goa to act as junior assistant to Mr. Ernest E. Sawyer, M. Inst. C.E., the Resident Engineer of the West of India Portuguese Railway, and of the Harbour Works at Mormugão. Here, by reason of his industry and ability, he was in 1885 promoted to senior assistant. Here also a career, bright with promise, was brought to an untimely end by a very sad accident. While one dark night proceeding along the railway in a trolley, the vehicle came into collision with some trucks. Mr. Erskine was thrown violently off the trolley, and the buffer-hook entering his leg he bled to death. He was elected an Associate Member of the Institution on the 5th of February, 1884, having been previously a Student.

LUDOVIC STEWART RUDOLPH EWING, the younger son of the late Alexander Ewing, Bishop of Argyll and the Isles, was born on the 13th of February, 1856, at Bishopston, in Argyllshire. He was educated mainly at Glenalmond, in Perthshire, where he was at school from September, 1865, till midsummer, 1873. On leaving school he studied at Glasgow, and in April, 1875, began a course of instruction at the Crystal Palace Company's Engineering School under Mr. J. W. Wilson, M. Inst. C.E., where he remained until December, 1876. Afterwards, he was employed in New Zealand from August, 1877, until March, 1881. At first he was an assistant in the Public Works Department under Mr. John Carruthers and Mr. W. N. Blair, MM. Inst. C.E.; subsequently he was engaged for about three years in the General Survey Department, during which time he triangulated about 1,000,000 acres for the Government, and laid off about 35,000 acres in rural sections for settlement, including the necessary topography, roads, traverses, &c., under Messrs. Maitland and King. Early in the year 1882, after six months' holiday in England, he went to India to take up the position of Assistant Engineer on the Bengal Central Railway, then in course of construction. The hard work and daily exposure to the Indian sun, however, soon brought on an attack of fever and ague, and he was laid up in Calcutta for some time. When he recovered, it was thought advisable that he should seek a better climate, and through the friendship of Mr. Izat, Agent of the Bengal and North-Western Railway, he was employed on the extension of that line from Goruckpore to Bahreich, in Oude.

In the month of December 1884, while out hunting in company with Colonel Currie, Deputy Commissioner of Bahreich, and three friends, he was accidentally shot. The hunt was at once stopped, and he was carried into a neighbouring bungalow, a doctor being hurriedly sent for. He lost consciousness for some time, but eventually recovered, and although completely paralyzed, was able to be moved slowly towards Bahreich. Everything was done for him both at the time of the accident and afterwards by Drs. Corbett and Robertson; more especially was he indebted to the wife of the Deputy-Commissioner for her care and unremitting attention to him. He remained at Bahreich for nine months before it was possible to remove him to England, but in October he was brought home in order that he might have the best advice. The paralysis, however, would not give way to treatment, and in January 1886 a return of Indian fever completely prostrated him, leaving him so weak that on the 17th of March, 1886, he succumbed to an attack of pneumonia.

Ludovic Ewing was a most promising young engineer, very highly thought of by his professional associates in the work on which they were engaged. A red granite cross marks his last resting-place in the rural churchyard of Westmill, in the county of Hertford, with the appropriate words under his name :—

"Patient in tribulation."

He was elected an Associate Member on the 7th of February, 1882.

JAMES LANGMUIR was born in Paisley in the year 1850, and received his education in that town. At the age of sixteen he was articled to Mr. W. R. Copland, M. Inst. C.E., in whose service he acquired much experience in carrying out water- and drainage-works during an apprenticeship of five years. At the close of his apprenticeship, Mr. Copland appointed him Resident Engineer of the Callander Waterworks, which were carried out to the satisfaction of all concerned, and to the great advantage of the Burgh. A short time after these works were completed, Mr. Langmuir received an appointment on the engineering staff of the Glasgow Corporation Water Commissioners under Mr. James M. Gale, M. Inst. C.E., and he remained in that service up till his death, in November, 1886. He was very much respected by the Chief Engineer, and was gradually promoted in the service. When it was resolved, about a year ago, to proceed with the works for increasing the supply of water to Glasgow, Mr. Gale selected Mr. Langmuir for the post of Resident Engineer. He removed to Milngavie so as to be near the scene of his labours, and set to work full of hope. The first contract was for part of the duplicate tunnel between Loch Katrine and the service-reservoirs near Milngavie. The second was for the Craigmaddie Service-Reservoir, the embankment of which extends to about 1,500 yards in length, with a maximum height of over 100 feet. For some time Mr. Langmuir had only the first contract to deal with. The second brought a considerable increase of work, and more than a corresponding amount of responsibility. It does not seem to have occurred to any one that his mind was giving way under the strain, although, after his death, several of his friends recalled peculiarities in his conduct which did not attract special notice at the time. On the morning of his death, on the 17th of November, 1886, before entering the breakfast room he was informed that one of his men wished to see him, and he sent a message to the man to

wait for a few minutes. He then entered the room which he used as an office, and closed the door behind him. In a few seconds the report of firearms was heard. On investigation it was found that he had shot himself.

Mr. Langmuir commended himself to all with whom he came in contact by his modest estimate of himself. His manner was genial and pleasant, and those who knew him best will most regret his untimely end. He was elected an Associate Member on the 5th of May, 1885.

RICHARD LONGLANDS was born on the 30th of October, 1830, at Sutton Bridge, in Lincolnshire, his father, Joseph Longlands, being an architect and surveyor at that place. His first employment was in the office of the late Mr. H. H. Fulton, M. Inst. C.E., in London. He afterwards returned for a time to his father as an assistant, and was engaged in the extensive reclamation and drainage works of the estuary of the Wash.

For several years, until 1852, he was occupied in numerous surveys for the railways projected at that time. He then returned to Mr. Fulton, and was employed under that gentleman on the West End and Crystal Palace Railway and other engineering works until 1856. After an engagement on the drainage of Lord Cardwell's estate in Lancashire, he left England in December, 1857, having been selected by the late Mr. Rendel, amongst a number of men sent out at that period, to recruit the staff of the East Indian Railway, which had suffered heavily during the mutiny.

At first he was stationed at Rajmahal, afterwards on the Soane district, and eventually spent the last six years of his service on the survey and construction of the Chord Line of the East Indian Railway. On the completion of the main line, and the consequent reduction of the staff, he quitted the service of the company, having been for some years in the position of District Engineer, and returned to England in 1872, after fourteen years' service.

In the year 1878, seeking employment in India, after a short engagement with the Local Government in Bengal, he was appointed on the staff of the Sind, Punjab and Delhi Railway, and was finally transferred to Karachi, where the experience he had gained in his youth amongst the fens of Lincolnshire was much appreciated, and was of great service in the work carried on by that Company in the harbour at Karachi.

Constant exposure to the sun, overwork, and anxiety, told the usual tale; and after several attacks of sunstroke, from which he

had temporarily recovered, his health finally broke down altogether, and he returned to England in April, 1885. After lingering a few months, he died on the 10th of October, 1885. His death was much regretted by the few of his companions on the East Indian Railway who still survive. He was universally liked, his genial, cheerful, and merry disposition being much appreciated; and no one was a greater favourite or more popular amongst his comrades.

Mr. Longlands was elected an Associate Member on the 1st of March, 1870.

FREDERICK NEWMAN was born on the 6th of June, 1837. At a period when the education of young engineers was of the most happy-go-lucky nature, Frederick Newman's guardians had the prescience to endow him with a systematic training, much of the nature of the ideal one afterwards formulated by Sir John Fowler, Past-President Inst. C.E.[1] On completing his ordinary schooling, Mr. Newman was apprenticed for three years to a firm of mechanical engineers, Messrs. McGlashan & Field (the latter being the inventor of the well-known "Field" boiler). He then passed five terms (nearly two years) in the Applied Sciences Department of King's College, London, obtaining while there prizes for chemistry, and for manufactures, arts, and machinery. Finally, on leaving King's College he was articled for two years to Mr. James Simpson, Past-President Inst. C.E. On the completion of his pupilage, he at once obtained the position of Resident Engineer (under Mr. W. G. Brounger, M. Inst. C.E.) for the construction of the Patent Slip at Simon's Bay, Cape of Good Hope, remaining on those works till their completion in 1862. He then proceeded to Port Elizabeth, in the same Colony, and was for six months in the office of Mr. Robert Pinchin, a Government surveyor, during which time he passed the Government examination in trigonometrical surveying. In 1863 Mr. Newman returned to England, and rejoined the staff of Mr. Simpson, by whom he was sent to complete the Stockport District Waterworks, and he subsequently, in September 1864, took charge also for Mr. Simpson of the various operations necessary for the extension of the Bristol Waterworks. These works were completed in October 1867. In March 1868 the proprietors of the Montevideo Waterworks applied to their Consulting Engineer in England (Mr. Edward Woods, President Inst. C.E.) for an engineer

[1] Minutes of Proceedings Inst. C.E. vol. xxv. p. 219.

to carry out the proposed works. Mr. Newman was chosen, and a month later left England for South America. The Montevideo Waterworks, of which he was the designer, and which were carried out under his immediate supervision and responsibility, were inaugurated with great success on the 18th of July, 1871. During the progress of these works Mr. Newman had been permitted to advise and report on other schemes of a like character, and having thus formed connections in the country, he elected to remain there in private practice. He projected and reported upon several similar undertakings in the River Plate, and up to 1881 was engaged in the construction and equipment of the Buenos Ayres Sewage and Waterworks, but, owing to political complications and lack of funds, the works came to a standstill for a time, so he returned to England.

In 1882 he undertook a journey to the city of Mexico to report upon a scheme for supplying it with water, a concession having been granted to a London financier by the Ajuntamiento of Mexico. After this period, and from having spent several years in hot and unhealthy climates, his health failed, and although he was connected with several undertakings in South America, he was compelled to relinquish active pursuits, with a view to reinstating his health in England. But this was not to be, and after some few months of severe illness, he died on the 6th of August, 1886, at the comparatively early age of forty-nine.

Mr. Newman was a man of considerable attainments, and, from his long and practical experience in hydraulic matters, was frequently consulted by his friends in elucidating matters of an abstruse character, which, from his knowledge of the higher branches of mathematics, he was fully able to do; his scientific knowledge was always at the disposal of his friends who at any time appealed to him. He was elected an Associate Member of the Institution on the 16th of February, 1866, but his employment in South America as a contractor prevented his attaining the higher grade, to which he was otherwise fully eligible.

REAR-ADMIRAL BEDFORD PIM, the son of Commander Pim, a distinguished naval officer, was born in Devonshire in 1826. He entered the Navy in 1842, and in 1845 was appointed to H.M.S. "Herald," then detailed for a scientific voyage round the world. With the purpose of making astronomical observations, and collecting objects of natural history, Mr. Pim made, in the following

year, in company with Mr. Seemann, the naturalist, a journey across the Cordilleras of the Andes.

About this time the public began to feel uneasy respecting the fate of Sir John Franklin, who left England in 1845 on a voyage of discovery to the Polar regions; and, among other measures, orders were transmitted to the commanding officer of H.M.S. "Herald" to sail up Behring's Straits, and ascertain if any traces could be found of the missing ships.

In Behring's Straits Mr. Pim volunteered to remain during the winter of 1848–49 on board H.M.S. "Plover," and took advantage of the opportunity to make himself acquainted with the language and habits of the Esquimaux. He remained amongst them many months, and, ever keeping in mind the service in which he was engaged, was delighted to learn from them that guns of a different manufacture from those ordinarily supplied by the Russians had been seen in the hands of the Indians of the interior. To test the truth of this information, Mr. Pim obtained leave to attempt a searching journey, and, starting at an unprecedentedly early period, the 10th of March, accompanied only by an Indian half-caste, and scantily supplied with provisions and arms, he commenced his perilous expedition. For many days the adventurous traveller struggled over the frozen solitudes, being at one time three days with scarcely a morsel of food. The strength of the Indian at length gave way under the terrible privations, and Mr. Pim was compelled to push on alone, by great exertion obtaining assistance and rescuing the Indian. He also ascertained that the guns in question were not of Russian manufacture, but whence they came, or how obtained, is to this day a mystery.

On the return of H.M.S. "Herald" to England in 1851, after an absence of six and a half years, Mr. Pim found he had been promoted the previous year to the rank of lieutenant; at the college examination necessary for confirmation to that rank he passed at the head of upwards of thirty candidates, and was complimented by the admiral for his superior attainments, which would alone have secured his promotion.

Lieutenant Pim having carefully studied the Arctic question, entertained the opinion, then shared by many geographers, that there was an open sea round the North Pole, and that it was but justice to Sir John Franklin to look for him at the end rather than at the commencement of his voyage; he therefore proposed a careful search of the whole of the Northern Coast of Asia.

So great was the enthusiasm excited by this daring proposition, that when Lieutenant Pim went to St. Petersburg to lay his plans

before the Czar, Earl Russell, then Prime Minister, afforded material aid, and Lord Palmerston sent with him a special Foreign Office messenger. His Imperial Majesty, however, refused to grant the necessary permission to proceed, remarking to Lieutenant Pim that the risk and difficulties were such as no human being could overcome.

Lord Palmerston characterized the conduct of Lieutenant Pim as that of a "true Englishman," and he also gained the warm sympathy and friendship of Baron von Humboldt, who ever afterwards addressed him as his "very dear and brave young friend." Returning from St. Petersburg, Lieutenant Pim reached England in time to join the last Arctic Expedition, sent out by Government under the command of Sir E. Belcher; he was attached to H.M.S. "Resolute," and sailed from the Orkneys, in May, 1852.

Early in March 1853, the thermometer being at 57° below zero, he made a journey across the ice, employing dogs, for the first time in Arctic search, to draw one of his sledges. After twenty-eight days of severe toil, the journey resulted in the rescue of the crew of H.M.S. "Investigator," which had been frozen in upwards of three years, and was on the point of being abandoned. To use the words of Sir R. Murchison, President of the Royal Geographical Society, "Lieutenant Bedford Pim rescued that gallant explorer, Captain M'Clure, from *destruction*, enabling him, in fact, to complete the journey, which entitled him to the rewards of his Sovereign and from Parliament for completing the North-West Passage." And the then Hydrographer to the Admiralty, Admiral Sir Francis Beaufort, in addressing Lieutenant Pim, wrote: "I am free to say that the practical knowledge you obtained during the several years (nine) you remained in the surveying service, joined to the double *éclat* you acquired by the embassy to Russia, and by your having been the fortunate link of connection between the Eastern and Western Arctic Expeditions, will for ever stamp your name as the possessor of resources and of enterprise which cannot fail to carry you safely and speedily through all the uphill part of the profession." Finally, a Parliamentary Committee, appointed to inquire into the circumstances connected with the discovery of the North-West Passage, showed their appreciation of his conduct in the following terms:—

"We, the undersigned members of the Select Committee appointed to inquire into the circumstances of the Expedition to the Arctic Seas, commanded by Captain M'Clure, R.N., have had our attention drawn to the gallantry, perseverance, and judgment of Lieutenant Bedford Pim, R.N., as displayed in the rescue of

Captain M'Clure and the officers and crew of H.M.S. 'Investigator.'

"The instructions from the House of Commons did not allow of our including any name but that of Captain M'Clure in our report to the House, but Lieutenant Bedford Pim's conduct in the discovery of the 'Investigator' did not escape our notice, and we consider he is not only deserving of praise but of high reward."

Lieutenant Pim's next appointment was to H.M. gunboat "Magpie," and in her he did good service at the bombardment of Sweaborg and other minor affairs in the Baltic, where he received a wound in the leg from a splinter.

At the breaking out of hostilities with China, in 1857, he was given command of H.M. gunboat "Banterer," and took his frail vessel from England to the Canton River. A proclamation had been issued that the English did not intend to wage war against the people of China, but simply against the Mandarins, and immediately after Lieutenant Pim's arrival a Mandarin of high rank visited the town of Seelow, situated a few miles inland from the "Banterer's" station on the Canton River, and began what is called in China, to squeeze the inhabitants. The oppressed people appealed to him to take the Mandarin; and he determined, with a volunteer crew of fifteen men in all, to attempt his capture. The Government buildings in the centre of the town were soon reached, and as quickly searched, but no Mandarin found, and the treacherous townspeople surrounded the party, aided by about one thousand braves. Hemmed in on all sides by overwhelming numbers, the little band had literally to cut a road to the boat, which was reached after a most severe hand-to-hand fight; the Chinese then attempted to board, but Lieutenant Pim, who remained alone in it to cover the retreat of his few surviving followers, shot the leader of the boarding party, who was in the act of cutting him down, and whilst the Chinese fell back with his dead body, the boat, riddled with shot and encumbered with dead, went to the bottom; Lieutenant Pim, covered with wounds, succeeded in reaching the opposite side of the creek, and was rescued by the boats of H.M.S. "Nankin."

In this severe struggle only three escaped without serious injuries, the loss amounting to five killed and seven dangerously wounded—Lieutenant Pim himself receiving no less than six gunshot wounds of so severe a nature as to compel his being invalided home.

On leaving the station, the Admiral-Commander-in-Chief, Sir Michael Seymour, wrote to express his high sense of Lieutenant Pim's gallantry and firmness on this occasion.

On the 19th of April, 1858, Lieutenant Pim was advanced to the rank of Commander, and as soon as his health was sufficiently re-established to enable him to move, he accompanied his friend, the late Robert Stephenson, M.P., Past-President Inst. C.E., on a voyage to Egypt. After visiting the Isthmus of Suez, Commander Pim returned to England early in 1859, and read, before the Royal Geographical Society, a Paper on the Suez Canal, which received high commendation.

At this time the Board of Admiralty appointed Commander Pim to the command of H.M.S. "Gorgon," and dispatched that vessel to the River Tyne, with a view of popularizing the navy and encouraging the entry of seamen. So admirably was this duty performed, that to his exertions may be mainly attributed the subsequent steady growth of the naval reserve in the north of England. His next service was the settling a delicate question with France respecting the fisheries; this satisfactorily concluded, the "Gorgon" was dispatched to the West Indies, and employed on the coast of Central America for the prevention of any further filibustering attempts against Nicaragua on the part of General Walker. The "Gorgon," however, being in a very dilapidated condition, was ordered home in April, 1860. Commander Pim's career in this ship is soon told. He was sent to search for and aid the line-of-battle ship "Hero," with the Prince of Wales on board, then on the return voyage from America; and in November, 1860, sailed in the "Gorgon" for the Cape of Good Hope and coast of Africa station; but in the June following, having exchanged into and brought home H.M.S. "Fury," he paid that ship off at Portsmouth, and afterwards retired on half-pay, although perhaps more actively and usefully employed than at any former period of his life.

During his term of service in H.M.S. "Gorgon" on the coast of Central America, Commander Pim was very seriously impressed with the unsatisfactory condition of English interests in that part of the world (especially as regards the means of transit across the isthmus), and therefore brought his practical knowledge to bear on the subject.

With this idea he narrowly examined the Atlantic coast line, and selected a deep bay 40 miles north of Greytown as a fitting terminus for a great railway to cross the isthmus, and then commenced exploring the interior. Realejo was chosen as the Pacific terminus, and the project of a new through transit by railway across Central America started. Commander Pim at once purchased the entire Atlantic harbour from the King of Mosquito, and obtained

a concession from him for a railway through the intervening country between the Atlantic and Nicaraguan boundary line.

Next came the necessity for a scientific examination of the proposed route, and Commander Pim, accustomed to hardship and danger, and trained in the surveying school, determined to go through himself and then seek from the Nicaraguan Government a right to construct the line. In March, 1863, he sailed for Central America, accompanied by two civil engineers, afterwards joined by a third. His subsequent intercourse, however, with the Nicaraguan Government was not so fortunate. War having been declared with San Salvador, and a revolution having broken out at the same time, it was impossible to do more than open negotiations for the required concession. Twice was Commander Pim taken prisoner, and was at the city of Leon when the conclusive battle of the war was fought there; but he escaped unhurt, and returned to England to make preparation for returning in October of the same year. This time he thoroughly examined the entire western section, and collected scientific information till February, 1864, when he laid his concession before Congress, and, notwithstanding every effort to throw out the Bill, he had the satisfaction of triumphing over all opponents and gaining his object.

On his return to England he had the great disappointment to find that in spite of his untiring exertions he had to do his work over again, as the nature of the concession was not quite satisfactory to the capitalists in London; he had therefore to return a fourth time to get it altered. In this he was entirely successful, at the meeting of Congress, in January, 1865, though again opposed clause by clause.

This scheme was, however, not destined to be carried out, and for the next nine or ten years Captain Pim was occupied in such desultory pursuits as commended themselves to a half-pay officer. Being endowed with a most active mind, he turned his attention to politics, and twice contested, unsuccessfully, Totnes in the Conservative interest; but at the general election of 1874 he was returned for Gravesend. In politics he was an old-fashioned Tory, yet all his efforts in the House were directed to the subject of Naval reform.

In 1880 Captain Pim retired from Parliamentary life, and five years after obtained his flag rank. In the course of his career he was successively seaman, surveyor, explorer, fighter, engineer, financier, politician, journalist, author and lawyer, something of many things, and a good deal of a few. If amid this multitude of vocations he was not destined to rise to first rank in any one, he

will yet be remembered as a singularly upright and sincere man, perhaps too honest in his convictions, and in his mode of expressing them, for the majority of those with whom he came in contact.

His principal contributions to literature were "The Gate of the Pacific," in which he advocates his most cherished project—one to which, for more than twenty years, he devoted most of his time and study—"Dottings by the Roadside," "An Earnest Appeal on behalf of the Franklin Expedition," "The Negro of Jamaica," "The Eastern Question," "The Political Situation Abroad."

Admiral Pim was elected an Associate of the Institution on the 9th of April, 1861. He died at Deal on the 30th of October, 1886.

JOHN MILROY died on the 9th of October, 1886, at the age of eighty years. He was one of the remaining links between the present day and the early period of railway construction, in which the late Mr. Thomas Brassey played a prominent part. Mr. Milroy was associated with that eminent contractor in railway work so far back as in the construction of the line between Glasgow and Greenock, now belonging to the Caledonian Railway. Mr. Milroy subsequently acted as agent for Mr. Brassey and for Messrs. Brassey and Mackenzie in the construction of lines of great extent on the Continent, the first of them being that between Paris and Rouen, of which Mr. Joseph Locke, Past-President Inst. C.E., was Engineer-in-Chief. Mr. Milroy was also engaged in a similar capacity on the Rouen and Havre, the Nantes and Caen, and the Caen and Cherbourg, railways. A few years later he likewise represented Mr. Brassey in the construction of a length of nearly 80 miles of the Great Northern Railway; and there were various other railway undertakings with which he was connected, not only in this country but also in France and Italy. Indeed, a considerable portion of his life was spent on the Continent, where he became exceedingly well known and greatly esteemed on account of his personal character.

From 1865 to 1877, Mr. Milroy represented Messrs. Brassey & Co., the contractors for the Glasgow City Union Railway, and the whole of this work, the cost of constructing which amounted to about £700,000, was carried out under his direction.

For the important bridge over the River Clyde in connection with this railway, it was necessary to sink several cylinders through a bed of fine sand to a depth of about 90 feet below high-

water; and this first directed his attention to the subject of cylinder foundations. The engineers had contemplated using compressed air and excavating the material in the cylinders by hand; but Mr. Milroy conceived the idea of sinking them by an excavator which could be used without taking out the water, and he proposed to try such an apparatus. This led to the first design of his patent excavator, and after a course of experiments, it was gradually adapted practically to the form in which it has since been used. The cylinders of the bridge were all successfully sunk, and the work established the great utility of the excavator for cylinder-sinking in loose and sandy materials. Mr. Milroy contributed to the Institution a Paper describing this work.[1]

In the year 1870 he was consulted by the Engineers of the Clyde Trustees as to their proposals for building quay walls on cylinder foundations, and he suggested the adoption of brick cylinders, which was finally decided on; and in conjunction with Mr. Brassey he undertook contracts for the Plantation and Mavisbank Quays. In the former of these works the superstructure was built on foundation piers which were formed of successive rings of brickwork. In the construction of Mavisbank Quay, a marked improvement was made in the character of the subaqueous pier foundations, which were formed of concrete, the piers being most securely bound together. The Milroy excavator was here used to excellent purpose, enabling the piers to sink to depths of 50 feet to 60 feet, or 70 feet. These works are fully described in a Paper presented to the Institution by Mr. Milroy in 1873.[2]

The various works which Mr. Milroy carried out in the Glasgow district, including those for which he was sole contractor, cost nearly £1,500,000. After retiring from active life, he passed his remaining years on the estate of Torsonce, Midlothian, which he acquired in the year 1879, and which he occupied himself in improving and beautifying. He had been in failing health for some months previous to his death.

Apart from his special knowledge of subaqueous foundations, Mr. Milroy possessed a very sound judgment as to all kinds of contractor's work. He had great insight into the cost, and most suitable methods of carrying out engineering operations, and his wide and varied experience, combined with a complete knowledge of practical details, enabled him to detect at a glance any

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[1] Minutes of Proceedings Inst. C.E. vol. xxviii. p. 339.
[2] *Ibid.* vol. xxxv. p. 186.

symptom of waste or of unnecessary expense. His method of conducting work was honourable, straightforward, and judicious; his manner courteous and conciliatory, which, combined with great shrewdness and tact, enabled him frequently to smoothe over difficulties that with less judicious handling might have occasioned serious disputes and complications.

Mr. Milroy was elected an Associate of the Institution on the 6th of May, 1868. He was also a Fellow of the Royal Society of Edinburgh, and, though of a retiring disposition, took great interest in all that tended to promote the welfare of his fellow-men.

*** The following deaths have occurred since the 31st of December last, in addition to those included in the foregoing notices :—

Members.

Bower, John.
Bradford, Hugh Meller.
Cooke, James Samuel.
Denny, William.
Eads, James Buchanan.
Leather, John Wignall.
Ormsby, Arthur Sydney.
Phillips, John Arthur, F.R.S.
Tarbotton, Marriott Ogle.
Whitworth, *Sir* Joseph, Bart., D.C.L., F.R.S.

Associate Members.

Addenbrooke, Edwin.
Brook, Thomas.
Fawcus, Ernest Augustus.
Ross, Leathom Earle.
Wake, Charles Baldwin.
Whittington, William.

Associates.

Bolton, *Colonel Sir* Francis John.
Hunter, James.
Ravenhill, Richard.

Information respecting the careers and leading characteristics of any of the above is solicited, to aid in the preparation of future Obituary Notices.—Sec. Inst. C.E. *March* 25, 1887.

SECT. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

The Testing of Portland Cement for the Harbour-works of Calais and Boulogne. By F. GUILLAIN.

(Nouvelles Annales de la Construction, vol. iii., 1886, p. 88.)

In 1884, the French Minister of Public Works established a laboratory for testing Portland cement in Paris, with branches at Boulogne, La Rochelle, and Marseilles. As the result of a number of experiments carried out at this laboratory with more than 12,000 briquettes, a specification for the supply and testing of Portland cement has been drawn up, the details of which are given in this Paper.

To determine the weight of the cement, only the fine powder is used, which has passed through a sieve of 5,000 meshes per square centimetre (32,257 meshes per square inch). This powder is filled into a litre measure (1·76077 pint), with certain precautions which are specified. The weight of one litre of the kind of cement delivered, must be within 100 grams (3·5 oz.) of that of a litre of cement of similar fineness ground in the same manner; but derived from specially selected, heavy clinker from the same factory.

With regard to the chemical test, the cement must not contain more than 1 per cent. of sulphuric acid or sulphides in determinable proportion. Cements containing more than 4 per cent. of ferric oxide, or in which the ratio of the silica and alumina combined to the lime is less than 0·44, are to be regarded as doubtful. In mixing the mortar for testing, sea-water is specified, and both air and water are to be maintained at a temperature of 15° to 18° Centigrade (59° to 64·4° Fahrenheit) during the continuance of the experiments. The proportion of water to be used must be the same for all tests made on the same day with one and the same kind of cement, and the whole quantity of water must be added at once to the 900 grams (31·7 oz.) of cement used. The mortar is to be mixed with a trowel for five minutes upon a marble slab. The quantity of water is ascertained by a preliminary experiment, and the four following tests are given to serve as an indication whether the proportion of water added is correct:—

1. The consistence of the mortar should not change if it be gauged for an additional period of three minutes after the initial five minutes.

2. A small quantity of the mortar dropped from the trowel upon the marble slab from a height of about 0·50 metre (1·64 foot), should leave the trowel clean, and retain its form approximately without cracking.

3. A small quantity of the mortar worked gently in the hands should be easily moulded into a ball, on the surface of which water should appear. When this ball is dropped from a height of 0·50 metre (1·64 foot), it should retain a rounded shape without cracking.

4. If a slightly smaller quantity of water be used, the mortar should be crumbly and crack when dropped upon the slab. On the other hand, the addition of a further quantity of water—1 or 2 per cent. of the weight of the cement—would soften the mortar, rendering it more adhesive, and preventing it from retaining its form when allowed to fall upon the slab. It is recommended to commence with a rather smaller quanty of water than may be ultimately required, and then to make fresh mixings with a slight additional quantity of water.

In order to determine the time of setting of the cement, a portion of it is made into a mortar and filled into a cylindrical box of metal 0·04 metre (1·575 inch) in height, and 0·08 metre (3·15 inches) in diameter. The mortar is then shaken down by a few gentle blows, and the water which rises to the surface is allowed to remain. A needle of 300 grams (10·58 oz.) weight, and with a square section of 1 square millimetre (0·00155 square inch) is suspended over the box by means of a cord and pulley, and the initial set is considered to have taken place when the needle fails to penetrate the whole depth of the mortar if lowered gently upon it. The cement is said to have set finally when its surface will support the needle. Any cement commencing to set in less than thirty minutes, or setting finally in less than three hours, is to be rejected, and the final set must have taken place within twelve hours. In each case the time is reckoned from the moment the water is poured upon the cement.

The water-test is carried out by making pats or cakes of cement 0·08 to 0·10 metre (3·15 to 3·94 inches) in diameter and 0·02 metre (0·787 inch) thick in the middle, and running out as thin as possible at the edges. These are placed upon pieces of glass and immersed in sea-water at a temperature of from 15° to 18° Centigrade (59° to 64·4° Fahrenheit). These samples must show no cracks or bulging. Eighteen briquettes are used for the tensile test, the cement being mixed with a trowel in quantities of 900 grams (31·75 oz.) at a time, and worked for five minutes before use. The form of the briquettes and the machine for testing them are the same as those used in Germany, the breaking-section being 5 square centimetres (0·775 square inch). The moulds are placed upon a marble slab while being filled, and are allowed to remain upon it until the briquettes are perfectly set, when they are removed from the moulds, and, after the lapse of twenty-four hours from the time of mixing, are immersed in sea-water, which must

be kept at a temperature of 15° to 18° Centigrade (59° to 64·4° Fahrenheit) and which is renewed weekly. Six of the briquettes are broken after an interval of seven days, six after twenty-eight days, and the remaining six after eighty-four days. The mean of the three highest figures of each series of tests is taken as the tensile strength of the cement under examination. The minimum strength specified for the neat cement in seven days is 20 kilograms per square centimetre (284·5 lbs. per square inch) in twenty-eight days, 35 kilograms per square centimetre (497·8 lbs. per square inch), and at least 45 kilograms per square centimetre (640 lbs. per square inch) in eighty-four days. If, however, the strength in twenty-eight days is not more than 5 kilograms per square centimetre (71·12 lbs. per square inch) in excess of that at seven days, then it must be at least 55 kilograms per square centimetre (782·27 lbs. per square inch) in twenty-eight days, and in any case where this strength is not attained at twenty-eight days it must be exceeded in eighty-four. Tests of cement mixed with sand are also specified. The standard sand is produced by crushing quartzite obtained from quarries near Cherbourg, and sifting it through sieves of 64 and 144 meshes per square centimetre (413 and 929 meshes per square inch). That which remains between these two sieves is washed and dried, and constitutes the standard sand. 375 grams (13·227 oz.) of this sand is mixed with 125 grams (4·409 oz.) of cement, and water is added in the proportion of 12 parts by weight to 100 parts of sand and cement combined. The sand and cement are first carefully mixed in a basin or capsule, then the whole of the sea-water is added at once and the mixture stirred with a spatula for five minutes. In filling the moulds a small rammer, weighing about 200 grams (7·05 oz.) is used to beat in the mortar until water rises to the surface. The excess of mortar is then struck off with a straight knife-edge and the surface smoothed down. When the mass is sufficiently hard the moulds are removed, but the briquettes are allowed to remain upon the slabs in a moist atmosphere for twenty-four hours, after which they are immersed in sea-water and treated in the same manner as in the tests with neat cement. At the expiration of the seventh day the strength of the sand-cement briquettes should be at least 8 kilograms per square centimetre (113·78 lbs. per square inch), and in twenty-eight days 15 kilograms per square centimetre (213·35 lbs. per square inch). In twenty-eight days the strength should exceed that at seven days by 2 kilograms per square centimetre (28·45 lbs. per square inch). In eighty-four days the strength must be greater than at twenty-eight days, and at least 18 kilograms per square centimetre (256 lbs. per square inch). The eighty-four-day tests are only considered indispensable for those cements which may not have stood the two previous tests; but if, while the cement is in store, the eighty-four-day tests should be unsatisfactory it may be rejected.

The definition of Portland cement given in this specification

strictly excludes so-called puzzuolana cements, or those made of lime mixed with slag. The size of mesh of the sieve is not clearly specified, the thickness of the wire not being stated. The percentage of sulphides in the cement is said to be an indication of adulteration with blast-furnace slag, it being supposed that sulphates only are formed during the burning of Portland cement. The degree of fineness to which the cement must be ground is not specified, it being considered that very fine grinding increases the strength chiefly during the duration of the tests, and that the subsequent increase of strength is less with fine than with coarse cement.

W. F. R.

The Influence of Magnesia on Portland Cement.

By G. Lechartier.

(Comptes rendus de l'Académie des Sciences, vol. cii., 1886, p. 1223.)

The observations recorded by the Author were made during a period of eight years on different works executed in Portland cement. The cement used did not in any case contain sulphate of lime in an injurious proportion, and the sand with which it was mixed was of good quality. Some of the works were exposed to the air, others under water; but in all cases the results observed were the same. The cement, when mixed with water, set in a normal manner, and the mortar showed great strength at first; but after a certain period, sometimes several years, a slow and gradual action took place, resulting in the complete destruction of the works. Pavements and similar works increased in volume, at the same time retaining a considerable degree of hardness. Cracks gradually formed, and the force of expansion was such as to crack walls between which the pavement was laid. Even blocks of granite of considerable size were crushed, and in one case a linear expansion of 4 per cent. was observed. Specimens of mortar taken from about twenty of these works showed identical properties. On analysis, most of them were found to have been made with a cement containing 43·56 per cent. of lime, and 29·18 per cent. of magnesia. In one case only was the proportion of magnesia found to be as low as 12 per cent. In chemical composition such a cement represents a mixture of 81·72 parts of normal Portland cement, with 30 parts of lime, or its equivalent of magnesia. These dolomitic cements having been burnt at a high temperature, the free magnesia which they contained was at first quite inert. By degrees, however, this magnesia became hydrated, and consequently increased in volume, and as this took place long after the setting of the cement, complete destruction of apparently sound works ensued. In support of these views, it is stated that disintegration proceeded much more rapidly when the mortar was exposed to the action of water, as in the construction of reservoirs and fountains. Under

cover several years elapsed before the same effect was noticed. The quantity of water of combination in the cement increased with the disintegration of the mortar. A cake of the cement mixed with water and kept for a year in a laboratory, showed great strength, and on analysis it was found that the proportion of water and carbonic acid in the disintegrated mortar was much greater than in this sound sample.

W. F. R.

A Practical Treatise on Portland Cement.

(Traité pratique sur le ciment de Portland. Par E. Candlot.[1])

From the manufacturer's point of view, cement results from the careful calcination and grinding of a homogeneous mixture of lime and clay. The composition of this mixture varies between certain well-defined limits, and it is advisable to note the proportions which have been found to prevail in some of the best samples of Portland.

Silica	20	to	26	parts	in 100	parts.
Alumina	5	„	10	„		„
Oxide of iron	2	„	6	„		„
Lime	67	„	58	„		„
Magnesia	0·50	„	3	„		„
Sulphuric acid	0·50	„	2	„		„

Stale cement, or cement that has been badly stored, absorbs water and carbonic acid from the atmosphere. The condition of any sample may be speedily ascertained by subjecting a quantity of from 2 to 5 grams to the heat of the gas furnace. The loss in weight indicates the amount present of these compounds, and if the total loss is over 3 per cent. the cement is to be considered as defective. Adulteration can always be detected by analysis of the cement. The most common adulterant is blast-furnace slag, the presence of which may readily be known by the smell of the sulphuretted hydrogen gas which is evolved when the cement is treated with muriatic acid. Some have objected to this test, inasmuch as many cements to which no slag has been added emit this gas when submitted to the action of the acid, but the Author states that this is only true in the case of badly-made cements, in the calcination of which scoria have been allowed to form in the kilns.

Cement must not only be accurately compounded and carefully burned, but it also requires to be thoroughly ground, in order to enable it to combine freely with water. To test the grinding, the Author states that three qualities of sieves are employed which have respectively 324, 900, and 5,000 meshes per square centimetre (2,090, 5,806, and 32,257 meshes per square inch), but still finer sieves of silk, which admit only of the passage of impalpable

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[1] The original is in the Library of the Inst. C.E.: Tracts 8vo. vol. 419.

powder, may be used. A well-manufactured cement should leave no residue on the first of the sieves, from 1 to 2 per cent. on the one with 900 meshes, and a residue amounting to between 24 and 28 per cent. on the finest sieve. In practice a cement may be accepted which gives residues of 1 per cent. on the first, 5 to 6 per cent. on the second, and 30 to 35 per cent. on the finest sieve. The proportions of these residues furnish a very good index to the extent of the firing. The density of a cement is a term generally applied to the actual and not the specific weight; that is to say, to the weight of a given volume, the measure being filled so as to avoid as far as possible any compression of the particles; hence it follows that the density, as at present ascertained, would vary in accordance with the size of the vessel used as the measure; in the larger vessel the particles would pack together more closely, and thus indicate a heavier substance than in the smaller one. To avoid this source of error a standard measure of 1 litre is adopted, but even then it is necessary, in comparing different samples, to ensure that the particles of each are of the same size. With an equally fine grain it has been proved that well-burned cements are denser than those which have been less fired. First-rate cements never show a density of less than 1,000 kilograms per cubic metre (62·4 lbs. per cubic foot). Inferior cements may vary between 950 kilograms and 1,000 kilograms, but only bad cements fall below the former figure. At one time it was usual to specify a density of 1,300 to 1,350 kilograms per cubic metre (81·12 lbs. to 84·24 lbs. per cubic foot), a stipulation which compelled the manufacturer to resort to bad grinding and to produce an inferior quality of cement The specific gravity of good Portland runs from 3·05 to 3·15; bad cements may even fall below 3·0, but are never less than 2·8. The Author considers that the time required for the initial set of a cement should be carefully noted, and requires more consideration than it at present receives. The set of cement varies, of course, greatly in accordance with the temperature and amount of the water employed to gauge it. By taking advantage of these facts, and using cold water, the set of a cement, which is too rapid, may be retarded. The Author indicates the proportions of cement and sand which may be used with the best effect in the various kinds of work, and insists upon the importance of ascertaining the voids in the materials to be cemented, in order to estimate accurately the above proportions. An account is given of a quick-setting description of Portland cement, which will carry more sand than the usual cements of this character, such as Roman cement and Vassy cement, and the Author draws attention to the gain in rapidity of induration, and the greatly increased strength of Portland, which results from the use of a small quantity of a solution of chloride of calcium. Some rules and specifications for the employment of cement are given, together with Tables of curves showing the increase in tensile strength at various intervals, as also the results of tests for compression.

G. R. R.

The Effect of Peaty Impurities upon Cement Mortar.

By O. Lieven.

(Dingler's polytech. Journal, vol. cclxiii. 1887, p. 342.)

In the construction of a distillery a floor had been laid down with a mortar composed of 1 part of Portland cement, mixed with 3 parts of sand. It was watered daily, but remained quite soft for a month. This was at first attributed to defective cement, but upon investigation it was found that the cement was of good quality, while the sand used showed on analysis a percentage of 4·3 of humus or vegetable matter. It was granitic, and contained small brown grains, which were evidently fragments of peat. When tested with 3 parts of Russian standard sand the cement used showed a strength of 12·4 kilograms per square centimetre (176·4 lbs. per square inch); but when mixed with 3 parts of the sand under examination the briquettes did not set. When the standard sand was adulterated with 5 per cent. of pulverized peat the 3 to 1 mixture did not set. It is supposed that the humic acid combined with the lime of the cement, forming a compound which enveloped the particles of mortar and prevented setting.

W. F. R.

A New Formula for Compression-Members.

By Professor R. Krohn.

(Transactions of the American Society of Civil Engineers, 1886, p. 537.)

The object of this paper is to suggest a method by which the permissible working-stress for compression-members may be determined upon rational principles.

The Author remarks upon the imperfections of the well-known formulas that have been deduced for this purpose either from theoretical grounds or from experimental data. Theory indicates that if the pressure of the load acts directly along the axis of the column, there can be no deflection unless the load exceeds a certain fixed quantity; and that so long as the load is kept below this limit, the column is only strained by direct compression and suffers no bending stress. But this deduction is contradicted by the general results of experiment, which show that in practice the column begins to bend slightly with even a moderate load, and is actually ruptured by a load which, according to theory, should be insufficient to produce any deflection.

This discrepancy proves the incorrectness of the assumption on which the theory is grounded, viz., the assumption that the pressure

acts exactly in the line of the column's axis. In practice it is impossible tó fulfil this ideal condition; for even in carefully prepared test-pieces it will be interfered with by unavoidable imperfections of workmanship and inequalities of the material, and to a still greater degree in the case of praçtical bridge-members.

It would therefore appear more reasonable to assume from the first that the straining force will be applied in a line more or less eccentric to the axis of the column. The calculated strength would then depend upon the extent of the assumed eccentricity, and the question arises whether it is possible to determine that quantity. It is evident that the initial eccentricity is subject to no definable law; and experiments indicate that it varies widely in different cases; so that it will only be possible to rely upon a certain lower limit of strength corresponding to the greatest extent of eccentricity that is likely to occur in ordinary practice.

The Author considers that it would be a difficult task to determine this limit. For such a purpose it would be useless to refer to the usual tests which are carried to the crippling-point; and reference could only be made to the deflection of struts as observed when the fibre-strain is within the elastic limit. But if a maximum eccentricity were deduced in this way from any particular series of tests, it could hardly be taken as a maximum applying to all cases.

In view of this difficulty the Author proposes to treat the question by analogy with the case of tension-members. Whether a member is intended to be used as a stiut or as a tie, the same care will be taken in the selection and manufacture of its component parts, and there is no reason to suppose that the unknown eccentricity is any greater in one case than in the other; although its effect in the case of the tie is commonly neglected, or is it at all events covered by the usual factor of safety. The additional fibre-stress produced by a given eccentricity, is of course greater in the strut than in the tie; but the Author claims that the ratio between the fibre-stresses in these two cases can be determined, and that the working-load for struts may then be fixed with the same degree of security as in the case of tension-members. Accordingly an approximate formula is found for expressing the greatest compressive stress C in the extreme fibre of a strut having a certain eccentricity a; and the tensile stress T in the extreme fibre of a tie having the same eccentricity is expressed by another formula. Then the ratio between the extreme compressive stress and the extreme tensile stress is of course denoted by $\frac{C}{T} = n$. Therefore if it may be assumed that the strength of the material is the same in compression as in tension, the working-load for struts must be one-nth of the working-load for ties, in order that the extreme stress may have the same intensity in both.

The Author proposes to adopt this principle for cast-iron as well as for wrought-iron and steel; and the formula for the working-load in struts of either material takes the following form:—

$$\text{Working load} = \frac{k}{1 + \frac{1}{8}\frac{k}{E} \cdot \frac{l^2}{r^2}},$$

in which k = the working-load in tension.
E = the modulus of elasticity.
l = the length of a round-ended column.
r = the radius of gyration.

And the Author takes the following values:—

for wrought-iron	k = 10,000 lbs.	E = 26,000,000.
„ steel	k = 15,000 „	E = 26,000,000.
„ cast-iron	k = 10,000 „	E = 13,000,000.

In conclusion it is remarked that for long and slender columns, steel cannot be used with the same advantage as in short massive columns or in tension-members; and that to use steel economically in compression-members it will be necessary to employ such sections as will give a large radius of gyration in proportion to the length.

T. C. F.

NOTE.—This method aims at making the ratio $\frac{\text{max. fibre-stress}}{\text{breaking-stress}}$ a constant quantity for ties, and for struts of all proportions. The Paper does not go on to enquire what will then be the value of the practical factor of safety, or $\frac{\text{working-load}}{\text{breaking-load}}$. But if the working-load is computed for long struts by means of the formula, and compared with the breaking-load as found by experiment, it will be seen that the factor of safety decreases as the length increases, and that the extent of this decrease is very considerable.—T. C. F.

Spring-Testing Machine. By A. LAURENT.

(Revue Générale des Chemins de fer, November 1886, p. 263.)

A new testing-machine for trying springs of all dimensions has been designed and constructed for the workshops of the Southern Railway of France. It consists of a vertical steam-cylinder supported by four columns, by which it is connected to a block based on a wooden platform let into the ground. The ends of the springs to be tested are supported on two small four-wheel trucks, which run on a line of rails on the top of the block, whilst the buckle on the centre is directly under the ram or piston-rod.

The cylinder is 24 inches in diameter, and has a stroke or vertical range of 31 inches. The total maximum pressure exerted with steam of 6 atmospheres is about 17½ tons, applied to the middle of the spring. Steam is admitted above the piston through an orifice of very small section, and the pressure of the steam as the piston descends is always in equilibrium with the resistance of the spring.

By means of an indicator in communication with the upper end of the cylinder, and by a suitable connection, a diagram may be taken showing the pressure of the steam at every point of the stroke, the abscissas being the measures of deflection, and the ordinates the measures of the load.

The cost of the machine completed and erected was £168. In the course of the year 1885, it served to test ten thousand springs. It is capable, in case of need, of testing two hundred springs per day.

Sample indicator-diagrams are given in the original article, illustrative of the action of the machine.

D. K. C.

Castelet, Lavaur, and Antoinette Bridges. By — SÉJOURNÉ.

(Annales des Ponts et Chaussées, 6th series, vol. xii. p. 409, 9 plates and 15 woodcuts.)

The Castelet bridge over the Ariège, and the Lavaur and Antoinette bridges over the Agoût, consist each of a single large arch springing below the surface of the ground on the slope of the river banks, and having open viaducts forming the haunches. Their spans are 135 feet, 202 feet, and 164 feet respectively; and they were built in 1882–84. The adoption of a large arch was expedient at Castelet, owing to the skew of the crossing, and the force of the current in a contracted rocky channel encumbered with boulders to an indefinite depth; and was economical at Vielmur, on account of the river foundations being 26¼ feet in depth. At Lavaur, where there was no difficulty in respect of foundations, the existence of a single-arched bridge, of the 18th century, in the vicinity, suggested a similar construction. The Castelet bridge, at its intrados, describes a circular arc, with a radius of 72 feet 10 inches and a rise of 46 feet: at the Antoinette bridge, the radius of the arch is 101¾ feet, except towards the base, on each side, below the surface of the ground, where the radius is reduced to 20⅓ feet, and the rise is 52 feet; and at the Lavaur bridge, the arch has a radius of 102⅓ feet above, and of 64½ feet below the surface, and a rise of 90 feet. The thickness of masonry at the crown of the arch is 4 feet 1¼ inch at Castelet, 4 feet 11 inches at the Antoinette bridge, and 5 feet 5 inches at Lavaur; whilst it is 7 feet 4½ inches, and 9 feet 2½ inches at 30° above the horizon in the Castelet and Lavaur bridges respectively; and the joint of the springing at the Antoinette bridge is 7½ feet wide. The various parts of the bridges, and their methods of construction, are very fully described in the article. The total cost of the Castelet bridge was £8,280, of the Lavaur bridge £19,400, and of the Antoinette bridge £8,960: their cost per lineal yard was £114 10*s*., £142 11*s*., and £91 1*s*.; and per cubic yard, £4 1*s*. 2¼*d*., £2 4*s*. 6*d*., and £2 16*s*. 7*d*. respectively. At the end of his elaborate description of these bridges, the Author adds some details of the old

Lavaur bridge, built in 1773–1791, with a single arch, having a span of 160 feet and a rise of 64 feet; and he concludes with some practical remarks upon arches of large span. Arched bridges rarely fail except at their foundations. Thus many of the largest Roman arches are still standing; and the Vieille-Brioude arch, of 178 feet span, has stood without maintenance for four centuries. The Trezzo arch, of 237 feet span, stood for forty years before it was destroyed. At Neuilly, arches of 128 feet span settled 3 feet, owing to the non-adherence of the mortar, without falling; and settlements of 1 foot 8 inches, and 1 foot 6¾ inches, took place in the piers of the Alma bridge, and of a bridge at Nantes respectively, without injuring the arches. The Souppes experimental arch of 124½ feet span, with a radius of 280½ feet, indicated how small a rise in a span could be reached, with excellent materials and unyielding foundations, without involving inadmissible pressures; for the mean pressure at Souppes was 41·8 tons per square foot, and the arch did not give way till the pressure at the crown reached the breaking-weight of 416 tons per square foot. The pressures, moreover, may be lowered by giving a batter to the arches, by making the spandrel walls very open, and by employing the lightest materials for the least strained portions. It is not at all necessary to use exceptionally strong materials for large arches; for the bridges of Prazolo and Maretta, having spans of 131 feet, and the Diable bridge with a span of 180½ feet, were built with bricks whose crushing weights were 50 tons and 81·4 tons per square foot respectively. The resistance of the mortar is far more important; but even in this respect, the safe limits have not been nearly reached. Moreover, a large arch is more stable and less affected by vibrations than a small arch, and can therefore safely bear greater pressures. Construction in rings admits of very light centres; and building in segments localises the inevitable cracks resulting from settlement on the centres. Cracks on the removal of the centres may be avoided by very adherent mortar, well-filled joints, close-jointed masonry, and the allowance of a long period between keying-in the arch and the removal of the centres. These considerations lead to the conclusion that the span of masonry arches might be advantageously extended beyond the limits hitherto attempted.

L. V. H.

Renewal of the Anchor-Cables of the St. Christophe Suspension Bridge. By — Baum and — Herpin.

(Annales des Ponts et Chaussées, 6th series, vol. xii., 1886, p. 677, 1 plate.)

The anchor-cables, on the right bank of the St. Christophe suspension bridge, had been so reduced from the oxidation of the lower portions of the wires, by the oozing of fresh-water into the gallery, and the intermittent action of sea-water, that they needed

2 H 2

renewing in 1884. It was decided, instead of connecting all the strands of the up-stream cable with those of the down-stream cable by new wires passing round the block of masonry forming the anchor, that the suspension-cables should be cut above the entrance to the anchorage gallery, and terminated by bundles of wires, to which independent anchor-cables are fastened by means of pins at suitable connections. The section and number, moreover, of the anchor-cables have been made such that, with one of the cables removed for inspection and repair, the strength of the remaining cables is quite equal to the corresponding suspension-cables; and the anchor-cables have been so adjusted to their anchorage that the inclination of the land cables has not been altered. Formerly the two land cables, on the one side of the bridge, on entering the underground gallery, were united into a single cable of three thousand three hundred wires, which was joined to the cable from the opposite side, and rested at the bottom of the gallery, by means of five cast-iron bed-plates, against the masonry anchorage. The two land cables on the one side have now been cut, $8\frac{1}{4}$ feet in front of the entrance to the gallery, and separated into twenty branches united in pairs into ten bundles, which encircle a steel pin, 7 feet $10\frac{1}{2}$ inches long and $6\frac{1}{3}$ inches in diameter. The ten bundles, with a total sectional area of 36·16 square inches, transmit the tension of the two old land cables, of equal sections, to the pin, which is held back by eleven anchor-cables, each having a sectional area of 3·6 square inches like each bundle. Each anchor-cable has its wires spread out at its extremity, and bent back like a hook in the conical cavity of a casting, into which they are secured by a fusible alloy of tin, lead, and antimony. Four cylindrical holes at each corner of the casting receive the ends of two steel rods, which, being turned round the connecting pin, form the straps joining the casting to the pin; and double nuts at the four extremities of the rods, protruding from the casting, serve for tightening up the connection and regulating the tension of the cables. The anchor-cable, thus connected with the suspension-cables on the one side, turns into the gallery, where it rests, by means of ten cast-iron bed-plates, against the masonry anchor-block, and is connected to the junction pin on the other side in a similar manner. Each anchor-cable is formed of one hundred and twenty-seven wires, 0·19 inch in diameter, twisted in both directions, and carefully coated, both separately and together, with an anti-corrosive composition. The wires, which under the test-load would be exposed to a maximum strain of $11\frac{1}{2}$ tons per square inch, were proved to have a minimum resistance of 50 tons per square inch, and an average resistance of $53\frac{3}{4}$ tons. As the land portions of the suspension-cables, being subdivided near their connection with the junction pin into ten bundles, expose a greater surface to the action of the weather at this point, the wires of these bundles have been made one-tenth thicker, to allow for diminution in strength from this cause. Experiments on the portions cut off from the old cables showed that the wires

of these cables, erected in 1850, where uninjured, had lost hardly any of their primitive strength. Details of the method of execution are given; and the total cost of the work was £1,230.

L. V. H.

Hydraulic Swing-Bridge at Drontheim.

(Centralblatt der Bauverwaltung, 1886, p. 336.)

Of the two swing-bridges for the railway from the mainland to the new station, on an island at Drontheim, the western one is worked by hydraulic power.

The swinging portion of the bridge comprises two main lattice-girders, 154 feet 2 inches long, with cross-girders and platform for a single line of rails, pivoted on a central pier of masonry. The iron framework over the pier consists of two deep cross-girders and a circular drum or ring. These two girders form the upper bearing for the vertical shaft, tapering from 1 foot 3¾ inches to 9⅞ inches diameter, on which the bridge is raised and swung. In the ordinary state of the bridge this shaft bears simply its own weight, resting on two cast-iron framed collars, and its lower extremity on a 1 : 14 lever, the long arm of which, 9 feet 6 inches in length, works in an opening in the masonry, from the face of which it projects sufficiently to clear the pulley at its outer extremity. The chain which passes round this pulley is fixed at one end to the masonry of the pier, and at the other passes round a second pulley to the hydraulic piston. A chain is also carried round the drum or circular framing, fixed by a central pin to prevent slipping, the two ends being connected to hydraulic pistons working in cylinders at an angle with the lifting-gear, the whole of the hydraulic machinery being carried on staging in the line of the current, and overhung by the bridge when open. The water is supplied from the town mains at a pressure of from 73 to 103 lbs. per square inch. The lifting-gear being first brought into operation, the whole structure is raised ¾ inch to clear the edges of the bedplates, the whole weight being now carried on the central shaft resting on the lever, and through this by the chain attached to the face of the pier. The turning-gear is then started, the opening or closing, including lifting and lowering, occupying about one minute. At high-water the lever is submerged, but this does not in any way affect the working.

P. W. B.

The Vienna Junction-Railway Bridge over the Danube Canal.

By — Köstlin.

(Allgemeine Bauzeitung, 1886, p. 101.)

This bridge as first constructed, and now superseded by that later described, was opened for traffic in August 1860. Its design was similar in principle to that of the Prague and other bridges of the type known as "the stiffened suspension," each chain being made up of a top and a bottom member (in this instance about 4 feet apart from centre to centre) connected by "Warren" bracing. Under the test-load the results produced were such as to cause great apprehension, as the deflection was so considerable that it was with difficulty the induced gradient near the piers was surmounted by the test locomotives. The cause of this was afterwards found to be greatly due to the mass of masonry, into which the ends of the chains were anchored, not having become properly consolidated. This having been rectified, and the suspension-rods shortened, the bridge was opened for traffic a month later. In the course of time, however, it was proved that the failure of the anchorage had not been the sole origin of the excessive deflection, and a gradual increase in the distortion led finally to the appointment of a technical commission to investigate the question. In the summer of 1883, the experts, as a result of their examination, recommended that the suspension system should be replaced by a more rigid construction of iron; but in investigating the causes of failure, one of the most important was not discovered until the demolition of the chain-towers had been proceeded with so far as to lay bare the chain-saddle castings which rested on roller-frames; it was then found that the saddles were displaced, and that the induced strain consequently was confined almost entirely to the upper member of the chain instead of being equally divided between the two. This displacement probably occurred at the time of the first test, previous to the opening of the bridge.

The work of reconstruction was undertaken by the State Railway authority, being one of the six different companies having running-powers over the line. The new bridge comprises a main span (and side arches over roadways) of 228 feet 4 inches, with a rise of 20 feet 9 inches, carrying two lines of rails. It is formed by four wrought-iron vertical and diagonal braced ribs 5 feet 9 inches apart from centre to centre, with hinged skewbacks. A diagram is given, showing graphically the strains on the various members. The arch and spandrels are faced with ornamental cast-iron work, and the Author at some length discusses the means of improving the appearance and effect of engineering works of this description.

In reconstruction, the piers of the old bridge were considerably strengthened, and converted into abutments for receiving the thrust of the arch, the original width of 18 feet being increased to more than twice that thickness, and the thrust conveyed to the old work by massive granite voussoirs.

This work was commenced on the 26th of May, 1884, and the bridge opened on the 6th of December of that year, the traffic having been diverted over another route for a period of seven weeks during the erection of the arch. After the opening, the removal of the chains and masonry of the old bridge was carried out, and with painting, clearing away, &c., occupied another seven months. Details are given of the cost of the work, including removal of the old unincorporated masonry, dismantling chains, &c., amounting to a total of £13,873. The weight of the ironwork was 372·2 tons, and cost £21 11*s.* per ton, or £8,020. The test was made with a live load equal to 1·26 ton per foot of track; the maximum temporary deflection was 1·38 inch, or $\frac{1}{2000}$ of the span of 228 feet 4 inches, and the permanent set was 0·12 inch.

Plates of illustrations accompany the original Paper.

D. G.

On the Life of Rails. By — FUNK.

(Organ für die Fortschritte des Eisenbahnwesens, 1886, p. 221.)

When the construction of railways was beginning in Germany (1835–1840) it was thought that the life of the iron rails then laid would be from fifty to sixty years, and the life of the unimpregnated oak sleepers about ten years, but this was soon found to be an erroneous estimate. Even on lines with the most favourable curves and gradients, the life of the rails was found to be much shorter, and the life of the sleepers much longer than had been expected. For instance, on the older Hanoverian lines constructed in the years 1842–47, with a length of 432 miles of main line, and 82 miles of sidings, with very good gradients (worst 1 in 300), and curves of large radius, and with, for the then weight of locomotives and rolling-stock, a very strong cross-sleeper permanent-way with broad based rails, the percentage of rails and unimpregnated oak sleepers changed was:—

TABLE A.

During Number of Years from Opening of Line.	Iron Rails. Per cent.	Oak Sleepers. Per cent.
5	0·77	0·38
10	11·39	5·50
15	38·39	25·36
20	59·20	44·03
25	87·00	68·25

The rails which gave these results were almost all obtained from English makers, without any specification as to the method

of rolling or piling, and without any guarantee, but they varied very much among themselves. Thus, on the Hessian division of the Hanover-Minden line, where the rails were rolled in England in two heats, and under the supervision of a Hessian inspector, only half as many rails were replaced in a given time, as on the neighbouring Hanoverian division, equal loads passing over each.

Similar experiences on other lines induced engineers to give more attention to the rolling of rails, and German manufacturers were soon able to produce rails with a guaranteed life of from three to five years, and piled and rolled according to specification and under inspection.

Thus, on the new Hanover line (constructed 1852–56), with a length of 375 miles of main line, and 82 miles of sidings, the rails had a guarantee of three to five years, and were rolled as above, and the sleepers, which were of oak, beech and pine, were impregnated with zinc chloride under pressure. Here the percentage of rails and sleepers changed was:—

TABLE B.

During Number of Years from Opening of Line.	Iron Rails. Per cent.	Impregnated Sleepers. Per cent.
5	0·45	0·001
10	6·01	0·90
15	16·19	5·52
16	20·06	9·54

Meantime, experience has shown that the life of rails depends, not only on the material and modes of manufacture of the rails, and the tonnage passing over them, but also on—

The method of construction of the permanent way.
The relation of the weight of the engines and rolling-stock to the cross-section and weight of the rail.
The maintenance of the line.
The curves and gradients of the line.
The weather.
The speed at which the traffic passes over the line.

The attention of engineers was for a time turned away from these important points (except improvement in the construction of permanent way), by the discovery of the Bessemer process. Iron rails usually failed by the crushing of their heads, owing to the opening of the seams; the Bessemer rails, therefore, being made from one casting, promised a longer life.

The Köln-Minden Railway management in 1864, laid two important lengths of their line east and west of the Oberhausen with four different kinds of rails, and kept careful records of the maintenance with the following results:—

TABLE C.

Reference Number.	Description of Rail. (Pear-shaped head: length, 18 feet 6 inches.)	Laid in October, 1864.	Percentage taken up.		
		Number of Rails.	After Twelve Years.	After Fifteen Years.	After Eighteen Years.
1	Close-grained iron, Troisdorf . .	150	80·66	82·00	86·00
2	Cemented iron, Phoenix, Rührort.	150	68·00	74·00	74·00
3	Puddled steel, Funke and Elbers (Hagen)	12	33·33	41·66	58·33
4	Puddled steel, Eberhard, Hoesch, and Sons (Lendersdorf) . . .	12	33·33	41·66	41·46
5	Bessemer steel, Eberhard, Hoesch, and Sons (Lendersdorf) . . .	149	4·70	6·04	17·45
6	Bessemer steel, Krupp (Essen) .	147	4·08	6·08	9·52
7	„ „ Hoerde . . .	150	1·33	2·00	5·35

In a very few years these test-lengths showed the great superiority of the Bessemer steel rails, and from 1869 the Köln-Minden direction used little else.

The following Table shows the failures of steel rails which have taken place on that line from 1868:—

TABLE D.

Year.	Number of 21 feet 6 inch Rails laid to end of Year.	These became useless in the Line					Broken before they were laid.
		In consequence of Fracture.		From various Causes.	Total of useless Rails.		
		Through the full Cross-Section.	Through the Fish-bolt Holes.		Number.	Per cent. of Total Laid.	
		Number.	Number.	Number.			
1868	1,853	..	..	..	..	..	..
1869	21,867	20	3	8	31	0·142	3
1870	78,259	12	2	6	20	0·025	4
1871	139,618	34	6	14	54	0·039	18
1872	222,844	57	11	25	93	0·042	41
1873	340,300	212	41	89	342	0·101	173
1874	452,650	460	86	192	738	0·158	8
1875	504,634	216	41	90	347	0·069	2
1876	514,801	193	37	80	310	0·060	2
1877	527,868	106	47	166	319	0·060	4
1878	548,717	155	41	201	397	0·070	1
1879	561,664	92	96	267	455	0·077	2
1880	574,564	121	110	389	620	0·102	..
1881	584,288	125	92	297	514	0·084	..
1882–83	594,964	148	105	432	685	0·110	7
1883–84	613,085	150	76	544	770	0·116	..
1884–85	624,351	108	83	678	869	0·132	..
1885–86	632,666	130	92	616	838	0·121	..
..	..	2,339	969	4,094	7,402	1·123	259

From this it may be seen that on this busy main line, the steel rails laid since 1868 have had up to the present an average life of 11·7 years, only 1·123 per cent. having failed from all causes.

Of this number—

Per cent.	
31·6	failed by breaking through the full cross-section.
13·1	„ „ „ „ fish-bolt holes.
55·3	„ from various causes.
100·0	

The Table also shows that Bessemer steel rails will only become useless by the wearing away of their head by the rolling load.

The lengths of iron and steel laid east and west of Oberhausen, and referred to above (see Table C), have been very carefully watched, and the wear of the rails accurately measured. The following Table gives the results:—

For Description of Rails, see corresponding Numbers in Table C.	Wear of Rail in Millimetres							
	East of Oberhausen. Gradient 1 in 1,040. Curve radius 1,640 yards.				West of Oberhausen. Gradient 1 in 1,570. Straight.			
	After Twelve Years.	After Fifteen Years.	After Eighteen Years.	After Twenty Years.	After Twelve Years.	After Fifteen Years.	After Eighteen Years.	After Twenty Years.
1	4·31	5·01	5·73	5·93	2·44	2·94	3·75	4·06
2	4·41	5·89	7·67	9·34	3·47	4·05	4·36	5·00
3, 4	4·72	5·91	6·82	7·93	5·09	6·06	6·78	7·60
5	5·23	7·12	7·73	8·81	4·57	5·67	6·37	6·99
6	5·18	6·33	7·14	8·37	3·82	5·34	6·05	6·63
7	4·18	6·33	6·80	7·97	3·98	4·90	5·46	6·12
Average .	4·68	6·08	6·98	8·06	3·89	4·49	5·46	6·07
Equal to .	Inch. 0·184	Inch. 0·239	Inch. 0·275	Inch. 0·317	Inch. 0·153	Inch. 0·177	Inch. 0·215	Inch. 0·239

The load carried over the eastern length was in eighteen years (1864–1882) 57,810,000 tonnes (56,896,944 tons), over the western 44,066,000 tonnes (43,380,018 tons).

Hence, for 1,000,000 tonnes (or tons) of load carried, the observed wear is:—

Number as per Table C.	East of Oberhausen.	West of Oberhausen.
	Millimetre.	Millimetre.
1	0·099	0·085
2	0·13	0·099
3, 4	0·12	0·15
5	0·13	0·14
6	0·12	0·13
7	0·12	0·12
Average . .	0·12	0·12
	Inch.	Inch.
Equal to .	0·0047	0·0047

A modern steel rail may be worn down 15 millimetres (0·59 inch) before being changed. $\frac{15}{0 \cdot 12}$ = 125,000,000 tons = the weight of traffic which may be run over the rail on a flat line with easy curves before it need be changed. Allowing for a percentage of breakages, the life of such a rail will therefore be about fifty-five years, or about what it was expected, at the beginning of railways, would be the life of an iron rail.

Since 1879 accurate and widely extended observation on the wear of rails have been made in Germany, but the published results cover only so short a period as to make them not sufficiently trustworthy. Some particulars of the results arrived at are given in the Paper.

W. B. W.

Comparative Wear of Steel Rails of Different Profiles.

By — Coüard.

(Revue Générale des Chemins de fer, 1886, p. 207.)

The Author summarises the means by which progressively the duration of steel flange-rails has been increased, and the renewals diminished, as follows:—

1. The suppression of holes in the flanges. 2. The use of external dog-bolts for fastening down the rail. 3. Augmentation of the number of cross-sleepers per mile. 4. The use of broad saddles to prevent notching of the flanges of the rails. 5. The use of angle-fishplates, fastened down with four dog-bolts on each joint-sleeper. 6. Augmented length of rails. 7. Diminished curvature or rise of the profile of the head of the rail. With respect to this, the last amelioration, the Author cites results of wear of rails of different sections, from the same manufactory, on the line of railway between Achaud and Vergèze, in January 1883. The heads of the old and the new rails were both 2·36 inches wide.

The head of the old rails was struck with a radius of about 8 inches, for a width of 1·14 inch, continued laterally with a shorter radius, 1·14 inch only, finished with a ½-inch radius at each flank. The head of the new rail, on the contrary, was struck with a radius of about 8¾ inches, for a width of 1·81 inch, joined to the flanks with a curve of about ⅓ inch. Thus, the profile of the head is flatter in the new rail than in the old rail; and as the result of wear, it was found that the numbers of trains corresponding to a vertical wear of 1 millimetre, or $\frac{1}{25}$ inch, were as follow:—

Date of Measurement.	Old Rail.	New Rail.
April 21, 1885	74,600 trains.	116,000 trains.
February 22, 1886 . . .	92,000 „	137,000 „

The longitudinal rupture of rails is very rare on ways ballasted with broken stone. Such ruptures are much more numerous on roads having earthy ballast.

D. K. C.

Wear of Steel Rails. By — Caillé.

(Mémoires de la Société des Ingénieurs civils, 1886, p. 450.)

The Author communicates the results of wear of Bessemer steel rails which have been laid for more than twenty years on the Orleans railway. They were laid in 1864, and have borne the traffic of an average of thirty trains and eight empty engines daily. They are double-headed, and were manufactured at Imphy and Saint-Chamond. There are six hundred and seventy-five rails in all, and they have been laid by themselves about the middle of the Étampes incline of 1 in 25, half of them in a straight line, and half of them in curves. Two of these rails, chosen from amongst the most worn, were lifted and gauged in October 1884; and the others, in June 1885, from amongst the least worn. The profiles of the four rails have been compared with the normal section, and samples have been analyzed and tested for temper and tensile-strength. In the two most worn rails the reduction of height is nearly the same. The wear has increased from the ends towards the middle by nearly 2 millimetres, or $\frac{1}{12}$ inch, tending to show that the ends of the rails partly escaped the pressure and shock of the trains. The fish-plates had penetrated the lower heads of the two rails to a depth of ½ millimetre, or $\frac{1}{50}$ inch, for Saint-Chamond, and to 3·6 millimetres, or ⅐ inch, for Imphy. The lower heads have been reduced by rust 1 millimetre in width for Saint-Chamond, and 4 millimetres, or ⅙ inch, for Imphy. The upper head of the Saint-Chamond rail has yielded and become enlarged by 2 millimetres, or $\frac{1}{12}$ inch. Besides, a fringe has been formed at each side of the

head, enlarging the width from 2·36 inches to 2·67 inches. The Imphy rail is not enlarged.

By analysis, it appears that both rails contain a large proportion of carbon, and that they differ only in the proportion of manganese, which is 0·45 per cent. for the Imphy rail, and 0·07 per cent. for the Saint-Chamond.

The Author concludes that by the yielding of the upper head of the Saint-Chamond rail, the wear is in reality less than that of the Imphy rail, and that the rust which so deeply affected the Imphy rail has facilitated the hold of the fish-plates, and contributed to equalize the wear.

Of the two least worn rails, the wear of the Saint-Chamond is nearly the same as that of the first and of all the other rails. But in the second Imphy rail, the loss of height is 27 per cent. less than that of the first, the wear at the fish-plates is two-thirds less, and there is only half the corrosion of the lower head by rust.

The Author concludes, 1st, that the hardest steels, like mild steel, are comparatively inoxidizable; 2nd, that of the hard steels, the hardest are the best; 3rd, that rail-steel, if it is hard, should be of a better quality than that which is defined by a tensile resistance of 45 tons per square inch, the strength of the first Imphy specimen; 4th, that mild steel is not suitable for double-headed rails of the Orleans profile.

D. K. C.

Portable Steel-Rail Saw.

(Railroad Gazette, 1886, p. 789.)

The portable saw for cutting off the battered ends of rails, re-drilling and straightening them, was designed at the Industrial Works of Bay City, Michigan, and constructed and delivered on the Michigan Central Railroad, in March 1886. It is a strongly constructed iron car, made with 15-inch beams and channel-irons, on three four-wheeled bogies, with a tender. There is steam-power on the car for self-propulsion, and for working the machinery with which it is fitted. The rail to be treated is hoisted at both ends by means of two cranes, and deposited on the feed-carriage. The rail is clamped on the carriage, and fed to the circular saw by the operator on the platform. By this operation one end is cut, and for cutting the other end the rail is simply run through on the rollers of the other carriage into the proper position. While this alteration of position is being effected, another rail is hoisted by the cranes preparatory to the cutting of the first end. After both ends are cut the rail is run on the skidways, to the line of the double-spindle drill, and when drilled at one end its position is reversed on a turn-table, and the other end is drilled. If the rail be straight the treatment is now complete; otherwise it goes to the straightener, and thence is delivered on the ground, or on a car.

For working the machinery, a high-speed double-cylinder steam-engine of 22 I.HP. is employed, from which the power is transmitted through high-speed gearing to a countershaft, from which the saw, the double-spindle drill, and the rail-straightener are driven. The periphery-speed of this gearing is 2,500 feet per minute. The gearing is accurately balanced, and the teeth are very carefully cut. The saw is driven by means of a 16-inch belt, with a speed of 6,500 feet per minute. The most successful fusion-disks have a periphery-speed of about 2,500 feet per minute, and at this speed steel rails of 65 lbs. per yard have frequently been cut through in fifteen seconds. Every working part of the machine is balanced.

By the portability of this machine, a great saving is effected in expense of transportation of rails for long distances. The average daily work performed by the machine is epitomized as follows, for the three months, July to September, 1886:—

	July.	August.	September.
Number of rails	180	180	186
" cuts.	360	360	372

These averages are for working-days only. All the rails were re-drilled, and, when necessary, straightened. About 20 miles of re-cut steel rails have been relaid. The machine is now in operation at St. Thomas, Canada.

D. K. C.

Advantages of Metal Sleepers. By S. Cantagrel.

(Mémoires de la Société des Ingénieurs civils, 1886, p. 88.)

In a communication from Mr. Cantagrel on entirely metal way for railways, he sums up the evidence of its advantages in abstracting the results of various experience.

Mr. Demoly, of the Algerian railways, recognized, in 1881, that the Vautherin sleeper was absolutely inoxidizable after having been tempered in coal tar, very stiff and unyielding when laid in good ballast and of great durability under good conditions, lasting twice as long as wooden sleepers on lines of light traffic.

Mr. Mazières, engineer of the same railways, stated, in 1885, that it appeared from the results of eighteen years' trial on the Algiers and Oran Railway, that the Vautherin sleepers act well; that they do not oxidize nor lose their original shape; that they cost less for maintenance than wood sleepers; but that, for the first three years, it is necessary to give special attention to the fastenings. He adds that not being flat-fronted at the ends, they do not resist lateral shocks, and give trouble on curves of short radius.

This last observation accords with the unanimous opinions of railway engineers. Mr. Mayer, of Berlin, in 1884, declared that the

wooden sleepers are much preferable to the iron sleepers for that reason, and also because they are heavier, and that their frictional resistance on the ballast is greater.

Mr. Webb, in order to augment the frictional resistance, tempers his sleepers in coal-tar and sand to roughen the surfaces.

With regard to durability, the ninety thousand metal sleepers laid eighteen years ago on the Algerian railways, having curves of 25 chains radius, and inclines of 1 in 62, are all in perfect order, and are likely to last fifteen or twenty years longer.

Mr. Post states that between Paris and Bondy, on 13 miles of way, 20 per cent. of the iron sleepers have been renewed in twelve years. In other places, for an equal length of time, the renewals have been less than 20 per cent. On the Algerian railways, in seventeen years, the renewals have been less than 4 per cent.

For comparison, Mr. Funk, of Cologne, is quoted on the life of wooden sleepers:—

	Injected with Sulphate of Zinc.	Not injected.
Oak	19·5 years.	13·6 years.
Red or white pine . . .	12·0 „	6·1 „

Mr. Mathieu states that the life of creosoted sleepers of oak is eighteen years; of beech, nine years; of Landes pine, twelve years.

The value of metal sleepers as old material is greater than that of old wooden sleepers. The cost of maintenance of iron sleepers diminishes after the third year; that of wood sleepers, on the contrary, augments with years. The fastenings of mild-steel sleepers do not wear loose, like those of wood.

The chances of rupture of metal sleepers are not so great as might be thought. Mr. Jungbecker points out that, on the Bergisch-Markisch railways one hundred and seventy-two ruptures have taken place amongst two hundred and seventy-three thousand metal sleepers. The ruptures are from $\frac{3}{10}$ths per cent. to $1\frac{1}{2}$ per cent.

The paper is very fully illustrated with sections of metal way and sleepers, and is supplemented with much tabular matter.

D. K. C.

Iron and Steel Sleepers and Rails on German Railways.

By — Muskewitz.

(Zeitschrift des Vereines deutscher Ingenieure, 1886, p. 1025.)

The Author gives tabulated statistics of the use of iron and steel sleepers and rails on all German railways during the last five years. Tables 1 and 2 subjoined refer to sleepers.

(1) Renewals of Sleepers.

Year.	Length in Miles.	Number of Sleepers removed.				
		Oak.	Larch or Pine.	Other Wood.	Total (Wood).	Iron.
1880–81	35,539	1,540,785	1,487,545	21,252	3,049,582	8,147
1881–82	36,171	1,881,739	1,635,012	32,878	3,549,629	14,579
1882–83	36,947	2,136,322	1,463,734	20,686	3,620,742	14,818
1883–84		Figures not obtainable.				
1884–85	38,685	2,355,571	1,429,779	76,119	3,861,469	29,070

Year.	Number of Sleepers laid.					Diminution in Number of Wooden Sleepers.
	Oak.	Larch or Pine.	Other Wood.	Total (Wood).	Iron.	Per cent.
1880–81	1,471,973	1,036,318	214	2,508,505	393,655	17·7
1881–82	1,581,492	1,140,763	6,131	2,728,386	619,272	23·1
1882–83	1,761,791	985,187	4,442	2,751,420	710,084	24·0
1883–84		Figures not obtainable.				
1884–85	1,730,802	986,776	119,786	2,819,364	970,662	26·9.

(2) Total Number of Sleepers in use.

End of Year.	Length in Miles.	Number of Wooden Sleepers.			
		Oak.	Larch or Pine.	Other Wood,	Total.
1880–81 . .	35,539	31,870,835	24,402,722	632,833	56,906,390
1884–85 . .	38,685	31,228,938	24,423,512	613,066	56,265,516
Percentage relative to 1880–81 . .	+8·8	− 2·0	+0·08	− 3·1	−1·1
Percentage on mileage of 1880–81 . .	±0	−10·8	−8·7	−11·9	−9·9

End of Year.	Iron Sleepers.			
	Transverse.		Longitudinal.	
	Number.	Tons.	Miles.	Tons.
1880–81 . .	1,418,241	59,993	2,046·5	203,537
1884–85 . .	5,743,120	260,927	3,219·3	307,726
Percentage relative to 1880–81 . .	+305·0	+335·0	+57·3	+51·2
Percentage on mileage of 1880–81 . .	+296·2	..	+48·5	..

In 1880–81, 2,875·5 miles, equal to 8·1 per cent. of the total mileage open, were laid with iron sleepers; in 1884–85, 6,575·7 miles or 17·0 per cent. were similarly laid.

COMPARATIVE MILEAGE of VARIOUS SLEEPERS.

Year.	Transverse Sleepers.			Longitudinal Sleepers.	Percentage of Total Mileage.	
	Percentage of Transverse Sleepers.		Mileage.	Iron.	Transverse.	Longitudinal.
	Wood.	Iron.		Mileage.		
1880–81	96·73	2·43	33,442	2,046·5	94·10	5·76
1881–82	95·39	3·74	33,704	2,422·6	93·18	6·70
1882–83	93·51	5·63	34,270	2,636·5	92·76	7·14
1883–84	91·90	7·23	34,873	2,957·3	92·10	7·81
1884–85	89·97	9·18	35,416	3,219·3	91·55	8·32

(Small balance of length not accounted for.)

In substituting steel rails for iron, the section has on the average been slightly increased, as shown by comparison of returns in 1873 and 1881:—

Year.	Mileage of Iron Rails.	Average Weight per Yard.
1873	12,883·6	72·0 lbs.
1881	23,281·6	71·2 "

Year.	Mileage of Steel Rails.	Average Weight per Yard.
1873	1,967·1	73·7 lbs.
1881	9,312·9	72·0 "

P. W. B.

Reduction of the Radii of Curves in Rugged Country.

By JULES MARTIN.

(Annales des Ponts et Chaussées, 6th series, vol. xii., p. 141, 3 woodcuts.)

A Commission was appointed in 1885, by the Minister of Public Works in France, to investigate within what limits it would be possible to reduce the radii of railway curves, and the length of straight line between reverse curves; and the Report presented is given in full in the article. A list is given of various French and other European lines having curves of less than 15 chains radius, indicating that there are several lines having curves of 7½ chains radius on gradients of 1 in 40 to 1 in 29. Different rules have been adopted for calculating the elevation of the outer rail on curves, and for connecting this elevation with the level of the straight portion of the line; but it is generally agreed that

the super-elevation should be complete at the junction of the curve with the straight line or the connecting parabolic curve, and that the slope of connection should not exceed, if possible, 1 in 500. The permanent-way is usually made firmer on sharp curves by strengthening the fastenings of the rails, and increasing the number of sleepers; whilst on some English lines, a guard-rail is added on curves not exceeding 12 chains in radius. The straight portions between reverse curves have been reduced to 164 feet, and, in exceptional cases, down to 50 and even 20 feet; and on some lines a parabolic arc is not interposed. The working of these lines is accomplished with the ordinary rolling-stock; and the sharp curves are considered to have only a slight influence on the resistance to traction. The speed of the trains amounts to 37 miles an hour on the lines with curves of not less than 12½ chains radius, to 28 miles an hour on lines where curves of only 10 chains are common, and is limited to 15 miles an hour on the Prélouc and Podal line, which has curves of only 7½ chains radius on inclines of 1 in 29. It is expedient to interpose a parabolic arc between the curve and the straight portion, not only in order to proportionate the horizontal resultant of gravity to the centrifugal force at each point, but also to reduce the slope connecting the elevated rail to the level on the straight. The Commission approves the adoption of the above-mentioned curves for the corresponding speeds, with the proviso that they should only be used on inclines less by from 1 in 250 to 1 in 200 than the steepest incline on the particular section of railway. The formula recommended for calculating the elevation of the outer rail is $E = \frac{w\,V^2}{g\,.\,R}$; where E is the super-elevation of the rail in inches, w the width of gauge in inches, V the maximum velocity of the train in feet per second, g the force of gravity or 32·17, and R the radius of the curve in feet. The connection of the curve with the straight portion should be effected by a slope of not less than 1 in 333, combined with a parabolic arc; and slopes of 1 in 250 should only be introduced where it is important to reduce the distance between the parabolic terminations of reverse curves. A table annexed to the article gives the super-elevation of the outer rail, and the minimum length of the parabolic arcs, for curves of 7½ to 80 chains radius, in the case of speeds of 18½ to 50 miles an hour, and with connecting slopes of 1 in 500, 1 in 333, and 1 in 250. The use, on these curves, of double-headed rails resting on chairs with a large base is urged, on the ground that such rails are much better suited than flat-bottomed rails to resist the shocks of the front wheels of the engine. The rigid wheel-base of the engines should, if possible, not exceed 13½ feet; and a slight play in the axles, the adoption of radial boxes, and the employment of bogies, would be very advantageous for enabling trains to run round sharp curves without throwing excessive strains on the rails.

L. V. H.

The Relation between the Wheel-Base of Locomotives and the Pressure on the Sleeper-Bed in Permanent-Way.

By Dominik Miller.

(Organ für die Fortschritte des Eisenbahnwesens, 1886, p. 171.)

In a longitudinal sleeper permanent-way, the greatest strains occur when it is newly laid and the ballast not well beaten up, and when it is run over by vehicles with a short wheel-base and great wheel-pressure. Calculations made for the various systems of permanent-way with metal longitudinal sleepers now in use, show that the material of the rail is never strained to more than 10 tons per square inch, whereas steel rails will bear a load which strains them to 25 tons per square inch, without showing any appreciable permanent set. Thus were it only necessary to take the strength of the rail into account, in the ordinary longitudinal-sleeper systems the rail might be made much lighter, but this cannot be done as the pressure upon the ballast would then become too great. The chief necessity, therefore, in constructing a permanent-way with longitudinal sleepers is to get a favourable distribution of pressure upon the ballast, but in the case of cross-sleepers the chief point is to increase the moment of resistance of the rail.

To bring about a small pressure on the ballast there are two available methods; one is to give the greatest possible breadth to the sleeper, the other to give a suitable spacing to the wheels of the locomotives. Great wheel-pressure and small wheel-base occurring together produce the greatest pressure on the ballast.

In secondary lines, where the curves are sharp, the distance apart of the locomotive wheels may have to be regulated by the sharpest curve.

Let a pair of wheels (loaded with 14 tonnes) stand directly over a wooden cross-sleeper, 250 centimetres (8·2 feet) long, and 25 centimetres (10 inches) wide, and well beaten up for an equal length on each side of each rail, a length of 2 metres (6·6 feet) in all, the middle 25 centimetres (10 inches) of the sleeper being unpacked; let it be assumed that none of the pressure is transmitted by the rail to the neighbouring sleepers; then there will be a pressure

$$p = \frac{14{,}000}{200 \times 25} = 2 \cdot 8 \text{ kilograms per square centimetre on the ballast (39·8 lbs. per sq. inch).}$$

Taking for an example the Felda railway with its Hartwich rails—

The wheel pressure	$G = 2{,}500$ kilograms.
„ half distance between wheels	$l =$ 45 centimetres.
„ whole „ „ „	$L = 2l = 90$ centimetres.
„ wheel-base	$a = 2L = 180$ „

The moment of inertia of Hartwich rail $J = 693$ (centimetres.)^4
„ breadth of base of rail $b = 10$ centimetres.
„ modulus of elasticity $E = 2{,}040{,}000$.
„ coefficient of ballast C.

The calculation can be made in three ways.

(i.) According to the longitudinal-sleeper theory of Winkler—

$$p = \frac{G}{8\,A\sqrt[4]{J\,b^3}},$$

where

$$A = \sqrt[4]{\frac{E}{64\,C}}.$$

This only gives correct results while—

$$k\,l > 1$$
$$< 2{\cdot}356,$$

where

$$k = \sqrt[4]{\frac{C\,b}{4\,E\,J}}.$$

In the case under consideration, taking $C = 48$, its greatest value—

$$k\,l = 0{\cdot}77581,$$

so that the result arrived at—

$$p = 2{\cdot}13 \text{ kilograms per square centimetre,}$$

is of no value.

(ii.) According to the theory of Fuchs. Here the value of—

$$a = l\,.\cos\frac{\pi}{4}\sqrt[4]{\frac{C}{E\,J}}$$

must first be determined. The symbols have the same meaning as above, except that C is the coefficient of ballast per running centimetre.

When the value of a is found, p_1, the pressure per running centimetre of permanent-way, is found from Fuchs' Table,[1] whence dividing by b (= 10 centimetres) the value of p is obtained.

In finding p it does not matter whether Fuchs' coefficient of ballast ($C = 18$) is used, or the highest value obtained by Weber's experiments (48), (calculated for Fuchs' formula $48 \times 10 = 480$), the result obtained is the same.

$$p = 2{\cdot}8 \text{ kilograms per square centimetre.}$$

(iii.) A short examination, without taking into account the bending of the rails, gives the same result. As the new engines on secondary lines are usually three-coupled, it may be assumed that

[1] Organ für die Fortschritte des Eisenbahnwesens, 1886, p. 16.

the pressure of the middle wheel of the three is spread equally over the rail up to the middle of the spaces, between the middle wheel and the wheels on each side of it; hence

$$p = \frac{G}{L \, . \, b} = \frac{2{,}500}{90 \times 10} = 2 \cdot 8 \text{ kilograms per square centimetre.}$$

So that the pressure upon the ballast of the Hartwich rail of the Felda Railway is at least as great as that of the cross-sleepers of main lines.

Considering next the question how great the wheel-base of the locomotives for the Felda Railway may be, taking into account the radius of the sharpest curve, 80 metres (262 feet), it is assumed—

(1) That the total play between the flanges of the wheels and the rails should be the same for a secondary as for a main line, viz., 10 millimetres (0·4 inch); and

(2) That there is no widening of the gauge at curves.

Then, if in the three-wheel coupled engine the two end wheels are binding against one rail, and the middle wheel on the opposite side against the other rail, the other middle wheel is 10 millimetres from the rail (f = 10 millimetres).

Let R = radius of curve = 80 metres;
s = width of gauge = 1 metre;
h = depth of flanged wheel = 18 millimetres;
r = radius of wheel = 0·43 metre.

Then $\sqrt{2\,r\,h}$ is approximately the length of the running-edge of the rail in contact with which the flange of the wheel is at any given time, and the distance apart of the wheels—

$$L = \sqrt{f\,(2\,R + s - f)} - \sqrt{2\,r\,h}$$
$$= 1 \cdot 14 \text{ metre};$$

hence the wheel-base $a = 2\,L = 2 \cdot 3$ metres (7 feet 6 inches). This wheel-base would give a pressure on the ballast of

$$p = \frac{2{,}500}{114 \times 10} = 2 \cdot 2 \text{ kilograms per square centimetre.}$$

W. B. W.

The Burlington (U.S.) Brake-Tests.

(Railroad Gazette, vol. xviii. 1886, p. 506 *et seq.*)

These tests took place in July 1886 on a length of some 8 miles of the Chicago, Burlington and Quincey Railroad, between Burlington and West Burlington, Ia. Their object was to test the efficiency of various brakes applied to freight-trains. The following brakes were tested:—

The American Brake Company's direct-buffer brake, fitted to a train of fifty new and very heavy cars, averaging 27,500 lbs. weight and 40,000 lbs. capacity.

The Eames automatic-vacuum brake, fitted to a train of fifty new cars, averaging 21,000 lbs. weight, and 40,000 lbs. capacity, and belonging to the Indianapolis, Decatur, and Springfield Railroad.

The Rote direct-buffer brake, fitted to a train of fifty new cars, averaging nearly 24,000 lbs. weight and 40,000 lbs. capacity, belonging to the Chicago, Rock Island and Pacific Railroad.

The Westinghouse automatic air-brake, fitted to a train of fifty old cars, averaging a little over 24,000 lbs. weight and 40,000 lbs. capacity, and belonging to the Chicago, Burlington and Quincey Railroad.

The Widdifield and Button friction-buffer brake, fitted to a train of fifty old cars, averaging 21,000 lbs. weight and 40,000 lbs. capacity, and belonging to the Lehigh Valley Railroad.

The tests were carried out at an average rate of 5 or 6 runs of four stops each per day. The stops in each run were as follows:—

Stop 1.—On slight-descending gradient from speed of 20 miles per hour.

Stop 2.—On slight-descending gradient from speed of 40 miles per hour.

Stop 3.—On descending gradient of 1 in 98 from speed of 20 miles per hour.

Stop 4.—On descending gradient of 1 in 98 from speed of 20 miles per hour.

The general tests included three runs of four stops each for:—

1. Twenty-five-car (mixed loaded and empty) trains.
2. Fifty-car empty trains.
3. Fifty-car mixed trains.
4. Fifty-car loaded trains.

The records taken were as follow:—

(i.) On the engine the steam-pressure and pressure or vacuum of air was carefully noted by two observers at critical points during the four stops of each run.

(ii.) Immediately behind the engine came a dynamometer-car, which gave a continuous record of the pull or push on the tender drawbar during every stop, thus affording means of accurately dividing the total work done between the engine-and-tender brakes and the train-brakes proper. This has never been done before.

(iii.) A graphic record was taken in the middle car of the speed at each point of the stop, and of the pull on the brake-rods similar to those taken at the last English brake-trials.

(iv.) On the rear car of the train gauge-readings of the pressure in the brake-pipe, reservoir and brake-cylinder, were taken during each stop, and various details in the behaviour of the brakes noted. A telephone connection between the engine and each car enabled simultaneous signals to be transmitted.

The result of the tests left it clear that the buffer-brakes in their present form, if not in any form, were quite unfit for general use.

The Rote brake failed to do any perceptible braking whatever, not only in its first preliminary runs, but in its formal trial, after having had three weeks for re-adjustment.

The Widdifield and Button came out nearly as bad. It was the only brake which produced notably injurious shocks, even with trains of only twenty-five cars.

The American brake was successful with a train of twenty-five cars, but not with fifty. In its "service drop down hill," the train was quite beyond control, and put its brakes on and off by its own undulations alone, without any brakes set at the head of the train, thus showing that it could not have been hauled along the line for any distance without making a stop.

The radical difficulty with the buffer-brakes appears to be that their going on creates a force which tends to take them off, and *vice versâ.* What is required to render the buffer-brakes available is:—

(i.) To use only so much of the great pressure caused by the first impact as is desirable.

(ii.) To hold this pressure throughout the stop regardless of the draw-bar motion.

(iii.) To release, in some simple way, at the end of the stop, as heretofore.

These ends the American Brake Company hope to compass.

The tests showed that the action of the continuous brakes seems to be quite as good when the rear twenty of fifty cars are cut off, as when the brake is applied to the whole fifty, thus indicating a defect which is worth correcting, because none of the other difficulties which were anticipated in working such long trains have actually arisen. The application, release, and the supply of air have proved to be simple matters.

Not one of the competitors made what can fairly be called very quick stops as measured by the best performances on record. This is probably accounted for by the condition of the brake-blocks. In the English brake-trials great care was taken to see that the fit of the brake-shoes was perfect. No precautions as to this matter were taken by any of the competitors at the Burlington tests.

The following Tables give an equitable basis for comparing the records of the work done by the Westinghouse, Eames, and American brakes at Burlington. Every source of inequality in comparison, such as differences of speed, gradient, weight of cars, proportion of weight braked and unbraked, is eliminated. (For the method employed in calculating the Table, see Railroad Gazette, May 15, 1885.)

COMPARATIVE ABSOLUTE EFFICIENCY of EACH BRAKE in EACH STOP and CLASS of STOP.

Reduced to the uniform standard of the per cent. of retarding force to the weight on braked wheels available for braking purposes.

(For weights of train in each test, and official corrected notes of each stop, see Railroad Gazette, 29 October, 1886.)

Emergency Stops.	Westinghouse. 1	2	3	4	Average.
Engine and 1 car, straight, air, or vacuum	8·962	8·147	9·283	7·113	8·376
	10·874	12·487	11·024	11·160	11·386
Average engine brakes	9·918	10·317	10·158	9·137	9·881
25-car mixed, all braked	8·937	10·180	8·467	10·279	9·466
,, ,,	8·912	10·040	8·688	9·731	9·343
,, ,,	9·833	10·314	8·260	9·109	9·379
Average	9·227	10·178	8·472	9·706	9·396
25-car mixed; rear 12 cut out	9·820	11·090	10·415	10·323	10·412
50 empties, all braked	4·684	6·644	5·089	7·158	5·884
,, ,,	5·245	6·607	5·137	7·111	6·034
,, ,,	..	..	..	..	..
Average	4·965	6 626	5·113	7·135	5·959
50 empties; rear 20 cut out	8·401	9·026	6·228	9·197	8·213
,, ,,	..	..	..	..	..
Average	8·401	9·026	6·228	9·197	8·213
Hand train-brakes and driver-brake	3·246	3 889	3·874	5·300	4·077

Emergency Stops.	Eames. 1	2	3	4	Average.
Engine and 1 car, straight, air, or vacuum	9·489	8·870	9·894	8·598	9·213
	11·506	11·800	11·992	11·500	11·700
Average engine brakes	10·497	10·335	10·943	10·049	10·456
25-car mixed, all braked	7·137	7·340	7·210	6·240	6·982
,, ,,	7·785	7·023	7·504	7·667	7·495
,, ,,	8·796	7·472	7·514	7·593	7·844
Average	7·906	7·278	7·409	7·167	7·440
25-car mixed; rear 12 cut out	11·071	10·111	10·812	8·081	10·019
50 empties, all braked	4·930	5·592	5·711	6·141	5·594
,, ,,	5·008	6·056	5·874	6·843	5·945
,, ,,	5·700	6·521	5·952	6·886	6·265
Average	5·213	6·056	5·844	6·623	5·934
50 empties; rear 20 cut out	8·043	Abandoned.			
,, ,,	..				
Average	8·043	..	..	..	..
Hand train-brakes and driver-brake	Not tested.				

Emergency Stops.	American. 1	2	3	4	Average.
Engine and 1 car, straight, air, or vacuum	11·966	9·980	10·612	10·003	10·640
	15·907	14·558	12·580	13·150	14·049
Average engine brakes	13·936	12·269	11·596	11·576	12·345
25-car mixed, all braked	6·530	5·022	6·231	5·298	5·770
,, ,,	6·758	5·910	6·350	5·174	6·048
,, ,,	6·014	5·543	6·439	5·424	5·855
Average	6·434	5·492	6·340	5·299	5·891
25-car mixed; rear 12 cut out	8·953	7·518	6·882	5·765	7·280
50 empties, all braked	4·728	..	4·768	3·954	4·488
,, ,,	Abandoned.				
,, ,,					
Average	4·728	..	4·768	3·954	4·488
50 empties; rear 20 cut out	7·223	7·060	7·180	6·434	6·974
,, ,,	6·894	..	7·219	6·528	6·880
Average	7·058	7·060	7·200	6·481	6·940
Hand train-brakes and driver-brake	2·580	2·838	3·482	3·504	3·101

NOTE.—The Widdifield and Button and the Rote brakes are omitted from the Table, as they performed so few of the tests. The tabulated results in their case are to be found on p. 775, No. 46, of the Railroad Gazette for 1886.

Service Stops. Steam shut off at beginning of stop.	Westinghouse. 1	Westinghouse. 2	Westinghouse. 3	Westinghouse. 4	Westinghouse. Average.	Eames. 1	Eames. 2	Eames. 3	Eames. 4	Eames. Average.	American. 1	American. 2	American. 3	American. 4	American. Average.
25-car mixed; rear 12 cut out	8·774	10·726	9·443	8·648	9·398	8·831	8·117	6·732	7·145	7·706	7·143	6·032	6·425	5·308	6·227
50 empties, all braked . .	1·975	2·159	1·705	3·790	2·407	4·031	3·986	2·807	5·375	4·050	2·970	2·887	2·792	3·604	3·063
" " . .	1·631	4·311	3·537	4·398	3·219	..	..	..	..	..	..	..	..	..	..
Average	1·803	3·235	2·121	4·094	2·813	4·031	3·986	2·807	5·375	4·050	2·970	2·887	2·792	3·604	3·063
50 empties; rear 20 cut out.	6·204	7·122	5·720	9·187	7·078	5·670	6·622	5·214	7·118	6·156	4·555	4·861	5·021	5·257	4·923
Service Stops. Steam shut off 500 feet and 1,000 feet before stop-post.															
50 mixed cars	4·864	5·790	4·254	7·500	5·602	3·281	4·694	3·742	4·487	4·051					
"	3·656	6·029	5·131	8·189	5·771	4·065	..	4·312	5·655	4·677					
"	4·390	6·897	6·326	7·290	6·226	4·333	5·076	4·227	5·655	4·823					
Average	4·303	6·239	5·237	7·660	5·960	3·893	4·885	4·094	5·266	4·525					
50 loaded cars	7·176	8·320	5·677	8·560	7·433	5·102	5·185	4·775	5·897	5·240					
"	3·197	8·010	5·760	7·228	6·049	5·332	5·432	5·577	7·075	5·854					
"	4·639	5·937	5·426	6·628	5·658	5·119	5·259	5·200	6·141	5·430					
Average	5·004	7·422	5·621	7·472	6·380	5·184	5·292	5·184	6·371	5·508					

The way in which the efficiency of the brakes decreased with the length of the train is very clearly brought out in the Table, the decrease being more rapid in the case of the Eames brake than in the Westinghouse. The Eames began to fall off in efficiency when the train was increased beyond twelve cars, while the Westinghouse held its own till twenty-five cars length of train was exceeded. On fifty-car trains, both with the Eames and Westinghouse, the average efficiency of the brakes was about half that with trains of less than twenty-five cars, showing that all that was gained by more brakes at the rear was lost in decreased efficiency of those at the head, so that the quickness of the stop was not affected whether the rear half of the train had brakes or not. In case, however, of a break away, they would stop the two halves separately in about half the distance which would be required to stop the whole train if the brakes were applied from the engine.

The buffer-brakes lose efficiency with increased length of train in a greater degree than the others, while at Burlington the stops of the fifty-car buffer-trains were so violent as to render the very fair nominal records worthless as an indication of practicability. The buffer-brakes, however, did not in twenty-five-car trains compare unfavourably with the others in the matter of shock. The best comparative record made by a buffer-brake was on the fifty-car trains with only thirty cars braked, the advantage of having the twenty unbraked cars in the rear to compress the buffers being very great.

The diagrams [1] show how it is that the buffer-brakes are able to compare so favourably with the others. It is not that they work almost as efficiently as the air-brakes when they get into action, but that they get into action so much more quickly. As is to be expected from this, the air-brakes show the greatest efficiency in the longest stops (*i.e.* those in which there is most work to be done)—the No. 4 (40 miles an hour down hill) because the proportion of time during which the brakes were fully on was then greatest.

The Papers are illustrated with numerous diagrams and drawings. The tests are to be continued in April 1887.

W. B. W.

The Abt System of Ascending Steep Railway-Inclines.

By G. L. Molesworth.

(Report upon the "Abt system" of ascending steep inclines.) [2]

Mr. Molesworth, Consulting Engineer to the Government of India for State Railways, visited the Harz Railway, constructed on the Abt system, principally for the purpose of opening out mines, quarries, and ironworks in the Harz mountains. It is of the 4 feet 8½ inches gauge. It leaves the Blankenburg railway station for

[1] Railroad Gazette, October 22 and 29, 1886.
[2] The original is in the Library Inst. C.E.

Tanne, the terminal station, a distance of 19 miles, constructed to a ruling gradient of 1 in 16½, crossing several ridges. The sharpest curve has a radius of 9 chains, but the sharpest on the ruling incline is 14 chains.

The Abt system was devised to correct the defects of the Riggenback system, in which an iron ladder-rack is employed. These defects are: the difficulty and cost of accurate construction of the ladder-rack; inequalities of pitch of the teeth, due to variations of temperature; liability to concussion and wear of the teeth; inequality of strains on sharp curves; inability of the engine to work at high speed anywhere; difficulty of combining the traction of adhesion and that of the pinion on the same axle.

The rack employed in the Abt system consists of three parallel steel bars, about 4⅓ inches deep, ¾ inch thick, notched out on the upper edges to form the teeth, which are pitched at 4¾ inches; fastened together in cast-iron chairs, laid on Vautherin sleepers of steel. The rack-bars are so set as to break pitch. The locomotives have two distinct functions: traction by ordinary adhesion, and traction by pinions acting on the rack-bars. They are six-coupled wheel tank-locomotives, having two outside cylinders for adhesive traction, and two inside cylinders for working two coupled pinions, each of which has three rings of teeth to gear with the rack-bars. The power of the cylinder is transmitted through rocking-levers to the pinions, which are coupled by side-rods. The rings of teeth forming the pinion are put together with intervening india-rubber packing, to confer a degree of elasticity and adaptability.

The following are the leading dimensions of the Abt engines, with which, for comparison, those of the State railway locomotives, L class, are given. These are ordinary ghât engines intended for use on gradients of 1 in 45 or 1 in 50.

—	Abt Engine.	L Class.
Number of wheels	8	10
„ „ coupled	6	6
Diameter of coupled wheels	49·2 inches.	50 inches.
„ single „	29·5 „	33 „
Wheel-loads, coupled	44·5 tons.	31 tons.
„ uncoupled	12·4 „	10 „
Total weight	56·9 „	64 „ including tender.
Wheel-base	17·88 feet.	20·83 feet.
„ rigid	10·1 „	10·92 „
Diameter of cylinders, for adhesion	17·72 inches.	18 inches.
„ „ „ pinion-traction	11·82 „	—
Stroke of pistons, for adhesion	23·62 „	26 „
„ „ „ pinion-traction	23·62 „	—
Diameter of pinions	22·56 „	—
Tractive force, at 120 lbs. pressure, by adhesion	18,090 lbs.	20,218 lbs.
„ „ „ „ pinion-traction	17,522 „	—
Area of fire-grate	20·13 sq. feet.	19·25 sq. feet.
Heating surface	1,636 „	1,226 „

It is here shown that by the rack- and pinion-gear the tractive force of the Abt engine is nearly doubled. The general dimensions of the two engines do not differ very much. The cost of the Abt engine is £3,500.

The brakes on the Abt engine are four in number: two hand-brakes used in shunting, and two which act by preventing the free escape of air from the cylinders in descending steep inclines.

The train in which Mr. Molesworth was taken up the mountains consisted of one carriage, six wagons of iron ore, and one brake-van, making a gross train-weight of 120 tons. The steep gradients were ascended at the rate of from 5 to 6 miles per hour.

Mr. Molesworth believes that the Abt system may with advantage be adopted in several places on the Indian State railways.

D. K. C.

The Shunting-Station at Mährisch-Ostrau.

(Wochenschrift des österreichischen Ingenieur- und Architekten-Vereins, 1886, pp. 333, 334.)

At the Mährisch-Ostrau station, a large number of laden coal trucks arrive daily from different pits, and bound for different places. Up to 1880 the sorting of these trucks and making up the trains necessitated such an extensive staff, that the Kaiser Ferdinand North Railway Company resolved in that year on the construction of a shunting station (*Abroll-Bahnhof*) which would enable the trucks to be sorted mechanically, and in a cheaper and easier way, and occupying much less time than the old system.

The laden trucks arrive in a confused mass above the shunting ramp, which has a total fall of 1 in 100, but at the end of 1 in 200 only, and they are now pushed over one after another, and by means of a central switch are turned on to their respective lines, down which they travel by their own weight, and are stopped where required by the application of brakes, which formerly were simple wooden blocks, but in 1882 were replaced by iron shoes of a form given in the Paper. The distance at which the brakes are applied before the truck comes to a standstill is dependent partly on the distance it has to run down the incline and partly on the weather; in dry summer weather this distance is about a truck's length. The time taken to bring up a truck and shunt it down the incline is from fifty to fifty-five seconds; in summer about five hundred and fifty, and in winter one thousand twelve hundred trucks, are shunted in twenty-four hours. The working of the central switch is done from a tower, and the shunting goes on quietly without any waving of flags or shouting; but at night and during fogs the switchman is advised by someone calling out what trucks are coming to be shunted. It is of course necessary that the station should be thoroughly well lighted, for which purpose seventy gas-lamps—and at the principal shunting place three Siemens's burners in addition—are set up.

W. H. E.

Station of the Northern Railway at Hanover.

By — DURLACH and — SEELIGER.

(Zeitschrift für Architekten und Ingenieur-vereins zu Hannover, 1886, pp. 23 *et seq.*)

The Paper gives a very detailed and fully illustrated description of the various works in connection with the rearrangement and construction of passenger and goods stations, and of the workshops, locomotives sheds, &c., at and near Hanover.

The original station was erected in 1843–46 in the Ernst-August Platze, the rails being on the same level as the adjacent streets, and afterwards, together with the immediately adjacent goods station, workshops, &c., was gradually enlarged. until, in 1874, further extension at this site being impracticable, it was determined to undertake the works described, and carried out between the years 1875 and 1881. A plan of the general arrangement as existing in 1874 is given.

Although at first intended to erect the new station on an entirely different site in the suburbs, the damage that would be thereby inflicted on a portion of the trading community of the town, led to the retention of the old site for the passenger station, and the removal of the goods station, workshops, &c., elsewhere, the rail-level for the new works being raised to 14·76 feet (4·5 metres) above the former level, so as to do away with the crossing of streets on the level. The goods station and mineral yard (*Rohgüter Bahnhof*) were removed to the vicinity of the marshalling yard at Hainholz, and the workshops reconstructed still further westwards, viz., at Leinhausen, about 3 miles (5 kilometres) from the passenger station.

The latter comprises the actual platform station, and the building containing the booking-office, waiting-room, restaurant, imperial apartments, &c. (lit by electricity). There are six subways, of which three are for passengers, two for luggage, and one is for postal service, leading to four passenger and three luggage platforms provided with hydraulic lifts. The dimensions of the various rooms are given, amongst the principal being the booking-office hall, 100 feet by 83 feet 7 inches by 59 feet 8 inches high; the first- and second-class waiting-room, 45 feet 1 inch by 38 feet 8 inches by 37 feet 1 inch high; and the restaurant 66 feet 1 inch by 45 feet 1 inch by 37 feet 1 inch high. The third-class waiting-room is 62 feet 4 inches by 48 feet 6 inches by 37 feet 1 inch high; and the fourth-class 65 feet 7 inches by 42 feet by 37 feet 1 inch high.

The roof of the actual station is formed by two segmental arches of 23 feet 8 inches rise, and 121 feet 9 inches span from centre to centre of the supporting cast-iron columns, and an intervening space of 30 feet 4 inches span; the level of the springing is 23 feet 3 inches above rail-level. At mid-length there is a transept of 126 feet 2 inches span; the roof is altogether 549 feet 7 inches long, and covered with corrugated plates, excepting $\frac{1}{3\cdot6}$ of its area,

which is glazed. The principals are about 22 feet 1 inch, formed by a segmental arched plate-girder 1 foot $3\frac{3}{4}$ inches deep, the lateral thrust being taken by the tie-rod ($2\frac{3}{8}$ inches in diameter), which is connected to the girder above at seven points by verticals.

For calculation the following loads were assumed:—

	Weight of Roof. Corrugated portion.			Weight of Roof. Glazed portion.		
	$10\frac{1}{4}$	lbs. per sq. ft.	(50 kg. per sq. m.)	$20\frac{1}{2}$	lbs. per sq. ft.	(100 kg. per sq. m.)
Occasional load (snow) . .	$10\frac{1}{4}$	"	"	$10\frac{1}{4}$	"	(50 kg. per sq. m.)
	$20\frac{1}{2}$	"	"	$30\frac{3}{4}$	"	

The wind-pressure allowed for was $25\frac{3}{5}$ lbs. per square foot (125 kilograms per square metre).

Drawings are given of the more important road bridges, and the dimensions and cost of all.

The total cost of the whole of the works, after deducting for sale of surplus lands, &c., amounted to £974,000.

D. G.

The Locomotive-Engine Works of A. Borsig at Berlin.

(Glaser's Annalen für Gewerbe und Bauwesen, No. 224, October 1886, p. 143.)

These works were opened on the 1st of January, 1837, and closed on the 1st of October, 1886. For nearly half a century the locomotives of this firm have been despatched to every part of the world, and the Author states that, at the present period of depression and inactivity in manufacturing enterprise, a brief account of the remarkable achievements of their genial founder seems appropriate. August Borsig purchased a site for his works on the 5th of November, 1836, for 10,000 thalers (£1,500), and erected thereon timber sheds capable of accommodating at the outside fifty workmen. To start with he had only horse-power, but in a very few months an engine, made by himself, was erected. The first casting was produced in these works on the 22nd of July, 1837. An extension of the premises soon became necessary, and additional land was purchased for this purpose in January 1838. The area was subsequently further extended, until finally a sum of not less than 100,000 thalers (£15,000) had been expended upon the site. Subsequently the original factory was remodelled, to make place for the present handsome buildings, which were erected about 1870. The machinery was of the most perfect description, and five boilers furnished the steam for eleven engines, equivalent to 250 HP. In October 1838 the first railway in Prussia, the line from Berlin to Potsdam, was opened with great public rejoicings, and on this occasion Borsig, who was present, deter-

mined to construct a locomotive-engine himself. On the 24th of June, 1841, after immense efforts, and with the most simple appliances, the first German locomotive was completed, and was tried on the following day upon the Berlin-Anhalt Railway. It is worthy of remark that the authorities of the Potsdam Railway declined to allow a trial on their line, as their English engineers pronounced Borsig's work to be an imperfect, bungling contrivance. The Author cites this as only one instance of English conceit in believing no other country has the right to supply the world with machinery. This first locomotive was named the "Borsig." It stood all the required tests in a most satisfactory way, and led to further orders for the supply of locomotives for the Anhalt Railway. In 1842 eight engines were turned out, and ten in 1843. The hundredth engine was completed on the 29th of August, 1846. Sixty-seven locomotives were built in 1847, and on the 25th of March, 1854, the establishment celebrated the completion of its five-hundredth engine. The numbers rapidly increased, as the following totals will show:—

Locomotive No.	1,000,	completed	21 August,	1858
„ „	2,000	„	2 March,	1867
„ „	3,000	„	19 April,	1873
„ „	4,000	„	7 December,	1883
„ „	4,208 (the last)	finished	September,	1886

Borsig the elder died on the 6th of July, 1854, shortly after he had turned out the five-hundredth engine, and was succeeded in the management by his son Albert, who died in April, 1878, after which the works were carried on by a council of directors.

Of the three thousand seven hundred and nine locomotives, completed at the end of 1879, two thousand eight hundred and forty-five went to Germany, seven hundred and eighteen to Russia, fifty-nine to Holland, fifty to Sweden, twenty-seven to Austria, six to Denmark, and four to India. The fall in the price of locomotives has been so severe that the value of a complete engine last year was only about one-half the amount paid ten years ago, the average price per kilogram, complete and ready for use, including everything, copper, steel, iron, labour, &c., was only from 0·60 mark to 0·75 mark (3·3*d.* to 4·1*d.* per lb.). The reasons for the decline of the trade are discussed, and it is shown that the sixteen existing locomotive-engine factories in Germany are capable of supplying fifteen hundred locomotives per annum, a number greatly in excess of the demand. Many work-people who have been long in the service of the firm have to seek fresh places, and no less than six hundred and thirty-seven men, who had been twenty-five years and upwards in these works, have been dismissed.

G. R. B.

Automatic Controller of the Passage of Trains.

By — BRICKA.

(Annales des Ponts et Chaussées, 6th series, vol. xii., p. 647, 1886, 1 plate and 1 woodcut.)

Having divided the interval between two stations into sections, a transmitter, worked by the passage of the trains, is placed at each division between two adjacent sections, so that the number of transmitters is one less than the number of sections. As a train passes one of these transmitters, a signal, special to the particular transmitter, is sent each way to electric bells placed along the line, and to a receiver at each of the stations, indicating thereby the position of the train. A single wire serves for the whole interval between the two consecutive stations, and also serves for the traffic-signals between the stations. Four stations are generally sufficient in practice, and they could not be increased beyond five without inconvenient complications in the mechanism. Each transmitter consists of a contact-apparatus, two multipliers, and a battery. The short arm of a lever is placed in contact with the under-side of the rail in the interval between two sleepers, and its depression by the deflection of the rail, on the passage of a train, causes the longer arm to rise and touch a knob, which completes the circuit of the electric battery. The current thus produced releases the multipliers; and at the same time a derivation of the same current interrupts, by means of an automatic commutator, the communication between the battery and the lever. Accordingly, only the current started by the first wheel of the train acts upon the multipliers. The commutator is replaced in position by clockwork at the expiration of five minutes—an interval sufficient for the passage of the longest train. One of the multipliers is connected with the wire of the receivers, and the other with the wire of the electric bells. Each multiplier consists of a metal toothed-wheel, with a weight tending to turn it, but retained by the bar of an electro-magnet, inserted in a notch in the wheel. On the completion of the circuit, the electro-magnet, by attracting the bar, releases the wheel, which revolves till again arrested by the bar entering again a notch in the wheel. During the revolution of the wheel, a series of pins, placed on the wheel at equal intervals between the notches, come successively in contact with a plate pressed behind by a spring. In the multipliers connected with the receivers, the contact of each pin with the plate produces a current which passes to the line wire and to the receivers, so that each turn of the wheel furnishes as many currents as there are pins between two successive notches. In the multipliers connected with the bells, the contact of each pin with the plate causes, on the contrary, a break of the current in the wire connecting the electric bells; and a stroke on the bell occurs at each break of the current on all the bells of the section, so that each turn of the

wheel causes as many beats as there are pins between the notches. Accordingly, each transmitter can be distinguished by varying the number of pins in each; and the passage of a train past the four posts is indicated by one, two, six, and eighteen currents, and by one, two, three, and four strokes of the bell respectively. There are two receivers at each station, one for each direction. The receivers of two adjacent stations are worked by the single wire which connects the transmitters. The receiver comprises a recorder of the signals, a Morse instrument with a commutator in two directions for terminal stations, and in three directions for intermediate stations; a bell, a needle, and a Leclanché battery. The first commutator establishes communication, at pleasure, between the bell on the recorder and the line wire on the battery; and the second commutator admits also of the local battery and the recorder being put in communication. The recorder is fully described and illustrated in the article; it consists essentially of four wheels, connected by gearing so that one of them makes one-ninth of a revolution when the preceding one has advanced one-third of a revolution; and they are moved by a wheel with twenty-seven teeth, turned by clockwork through one division each time the passage of a current causes an electro-magnet to withdraw its bar, so that this toothed-wheel performs one complete revolution when a train has passed the four transmitters in succession, and thus developed twenty-seven currents. The three first wheels each exhibit two disks, which are either both red, blue and red, or red and blue, according to the position of the wheel, depending upon the passage of the train; the fourth wheel serves as a counter, advancing one division each time that a train has traversed the space between the two stations; and a fifth wheel furnishes a register of the number of currents passed through the recorder. The code of signals between the signalmen at the stations consists of one or more rings on the bells of the receivers; whilst the intermediate position of a train is indicated by the disks, and by strokes on the bell when passing a post. When the register is no longer at zero, and the signals of the recorder agree with the corresponding strokes on the bell, the appearance of two red disks indicates one of the following occurrences: an up-train travelling on the line opened for down-trains, or the reverse; two trains about to meet on the same line; a train entering a section before the train in front of it has left this section; or a portion of a train having broken its couplings and travelling backwards. The currents generated by each transmitter could be registered by interposing a Morse receiver on the line wire, the passage of each train past a transmitter being indicated by a series of dots; and the signals passing between the signalmen at the stations would be also recorded in the registering slip. The connections, moreover, of the battery of each station might be so arranged that no message could be despatched except when the protecting-signal is at danger.

L. V. H.

Experimental Hydraulic Station at Santhià.

By G. Saccheri.

(L'Ingegneria Civile, 1886, pp. 161–165, 1 plate.)

In Italy the ministry is about to propose to Parliament the construction of works for the carrying on of hydraulic experiments on a larger scale than has hitherto been done, either in Italy or elsewhere. It has been found necessary, in order to stop disputes, to have rules more certain than those hitherto used for determining the discharges from the different kinds of intake used on the Cavour Canal, and its subsidiary canals. It is clear that the same coefficients cannot be employed for both large and small discharges; and, moreover, each case has its own peculiar circumstances, to which it is important to be able to give proper values. The works are also to be used for the instruction of young engineers.

In 1869 a Commission investigated the subject; and in 1885 a second Commission was appointed, presided over by the eminent hydraulic engineer, D. Turazza, and consisting of various hydraulic engineers and professors. In their report, which was fully approved by the Board of Public Works, they recommended a very complete design, the principal points of which are worthy of notice.

The hydrometric station is to be placed on the right bank of the Cigliano Canal, near the town of Santhià.[1] Two distinct intakes are to be made which will reproduce two out of the five patterns of intake actually used on the Cavour Canal. The larger intake is capable of discharging 424 cubic feet per second, and the smaller 106. The ordinary intakes on the Cavour Canal consist of (i.) an aperture in the bank of the canal, (ii.) a masonry channel from 16 to 20 feet in length, (iii.) a basin at the end of which is the "module" or measuring-aperture. The experimental station will have these, as well as other channels, overflows, and apertures enabling various experiments to be made; and, in addition, two rectangular tanks, one large and the other small, for actual measurement of the water. Specially designed penstocks, or sluice-valves, are to be used, with the view of changing the direction of the flow suddenly and yet without shock. The valves for medium discharges consist of two pairs of sluice-gates, one of each pair being of iron and heavy (12 cwt.), the other of wood and light. One of each pair commands a channel to the measuring-tank, the other controls the access to the outlet-passage. Each pair is so connected together that when the heavy gate is dropped, by letting go a catch, the light gate is raised against the pressure of the water. Before the measurement begins, the measuring-tank is closed by one of the light gates, the heavy gate of the same pair controlling access to the outlet-passage being up, and the water

[1] Between Turin and Milan.

running away. At the proper moment this heavy gate is dropped, thus raising its companion light gate, and turning the water into the measuring-tank. When the experiment is over, the other pair of gates comes into play; the light gate of this pair controlling access to the outlet has been down all the time, and the heavy gate controlling access to the measuring-chamber has been up. Now if the heavy gate of this second pair is dropped, the water is immediately turned off from the measuring-tank into the outlet-passage. When the experiment is over and the tank is being emptied, the sluice-gates are re-arranged for another experiment. The valves for larger discharges are on a somewhat similar principle. The smaller measuring-tank is 26 feet by 23 feet by $6\frac{1}{2}$ feet deep, and contains 26,000 gallons, or 330 gallons for each inch of vertical height. As the maximum quantity to be used in this smaller tank is 66 gallons a second, there will be a rise of $\frac{2}{10}$ inch per second, and the experiment will last nearly seven minutes. The larger tank is 98 feet by 66 feet by 10 feet deep, and contains 422,000 gallons. Here, if the maximum flow of 2,640 gallons per second is running, the level of the water will rise nearly 1 inch a second, and the experiment will last two-and-a-half minutes. The total fall between the sill of the intake and the floor of the outlet is 26 feet. There is a self-registering gauge in a small hut alongside of each tank. Here the paper-cylinder is driven by the rising water, and, in order to give the intervals of time, the beats of a seconds pendulum are marked on the paper by aid of an electro-magnet.

J. G. G.

New Works for the Regulation of the River Isar.

By A. Wolf.

(Zeitschrift für Bauwesen, 1886, p. 515.)

In the regulation of a stream, one of the principal objects to be attained is the closing of unnecessary side channels, and its gradual training into the desired main channel. In Bavaria this is usually effected with the aid of fascine-work, the banks being gradually raised and strengthened, and finally secured against future injury by protecting with stone. In proportion as these training-banks are raised, so can the stream only overflow them when the water is at a more or less high level, and although there are in some cases openings left for the access of the stream to the old channel course at the back of the dam, the progress of warping by this method is very slow and uncertain. The Author is of opinion that he has devised a method by which the transfer of gravel, &c., from one part of the river to another, or the cutting away of projecting banks as desired, may be much more

rapidly and certainly effected. This method is by the employment of what he terms "Hangers" (*Gehänge*), each of which is formed by a row of wire-bound fascines laid side by side, and connected to a transverse pole or poles with wire-binding. These form a platform of from 6 feet 6 inches to 16 feet 6 inches (2 to 5 metres) long and a fascine-length in breadth, which is sunk, not to the bottom, but to a depth varying with circumstances (generally about summer water-level), allowing the current to flow above and below them, and being kept in this position, a horizontal one, by being attached to piles previously driven in the line desired.

The effect of these hangers is to increase the velocity of the stream immediately around them and to diminish it at their rear, thereby inducing a corresponding respective detrition and deposit, and causing the abandoned portion of the river-bed at their back to be filled up, and simultaneously the channel in front of them to be deepened. Upon their position in respect to the stream depends the effect produced, and it is generally most intense when the angle is acute. The method of fixing them in position is as follows:—Piles, 19 feet 9 inches long and 7⅛ inches by 9⅞ inches in section with wrought-iron shoes, are driven in a single or double row, according to the strength of the current, at a distance of about 10 feet (3 metres) in advance of the intended confines of the channel. These piles average about 8 feet 3 inches (2·5 metres) apart, and penetrate to a depth of from 10 to 13 feet (3 to 4 metres) into the river-bed. In the bays formed by the piles are fixed the hangers at either mean or low-water level, in such a way that open spaces of 16 feet 5 inches (5 metres) and hangers of the same length alternate, this arrangement being modified according to the rate of deposit required. The hangers are secured by lashing their horizontal poles with wire rope to iron pins driven at the requisite height into the piles.

The details of the cost are given; the fascines, of which there are four or five to each 3 feet 3 inches of hanger, cost about 1*s.* each; the piles, including driving, about 4*s.*, from which is deduced the average price per lineal yard of hangers, as from 2*s.* 9*d.* to 5*s.* 6*d.*, according to whether a single or a double row of piles is driven, and this price, in cases where the current is very strong, amounts to 7*s.* 4*d.* A description is given of the works actually carried out on the Isar on this system, viz., at the Oberpöringer Bridge, where the course taken by the stream threatened the destruction of the bridge and the rendering the channel unnavigable; the averting the destruction of the river-bank at the Gottfriedinger bridge, and at Neutiefenweg.

Cross-sections of the river, showing the effect of the hangers upon the scour, together with detail diagrams are given.

D. G.

The Canalization of the Main from Frankfort to Mainz.

(Centralblatt der Bauverwaltung, 1886, p. 407.)

The dimensions of the navigable channel to be maintained in the Main having, forty years back, been fixed on too small a scale, the traffic on the river had of late years very greatly declined; until, about twelve years since, various schemes were submitted to the Frankfort Chamber of Commerce, by which either the river was to be improved or a canal was to be constructed near either the right or the left bank. It having been decided to improve the navigation of the river itself, the works were, after some delay, commenced in the autumn of 1883, and have quite recently been completed and opened throughout.

The length of the canalized portion of the river is 22½ miles, and the total fall in this distance 34·12 feet; the mean flow of water in the dry season being 2,471 cubic feet per second.

The navigable channel in the river is prescribed to be throughout not less than 6 feet 6 inches deep, and the locks are arranged with a depth of 8 feet 3 inches, to which the whole channel may ultimately be dredged.

The works comprise five weirs and locks, of which the following are the leading dimensions:—

Place.	Height.		Length.		
			Open Channel.	Upper Canal.	Lower Canal.
	Feet.	Inches.	Yards.	Yards.	Yards.
Frankfort (on the Main)	9	0	438	624	328
Höchst	6	0	219	109	328
Okriftel	6	0	219	109	405
Flörsheim	6	0	219	109	339
Kostheim	7	6	328	109	1,313

The works first commenced were the weirs at Frankfort and at Höchst, which were ready in the spring of 1884, the navigation not having been at any time interfered with. The locks were first completed throughout, and then the canals above and below the locks: the weirs being the last part of the work carried out.

Movable weirs of the needle type, opened at flood time and for the passage of ice, have been adopted; the arrangements including also a fish-ladder (rising in long tanks by steps of 12 inches height), and a bywash (fitted with drum-weir), for the passage of timber-rafts, and such like floating material. At Frankfort the weir is placed 361 yards above the lower end of the lock, and the dimensions of the channels are:—

	Feet.	Inches.
Canal	86	2
Two flood-openings, each 142 feet 5 inches	284	10
Navigable pass	154	3
Flood-opening	87	4
Bywash	39	4
Total waterway	651	11

The weir replaces a rapid shoot of the river which has been one of the great obstacles to navigation. At the four remaining stations, the weirs are placed at the lower lock-gates.

The sills on which the needles rest are of sandstone on a concrete foundation, the channel being formed with stone setts. At the Frankfort weir the sill is placed at the lowest summer water-level, in the others rather lower; while the navigable pass has an additional depth of 2 feet. The sill is thus generally from 8 feet 3 inches to 10 feet 2 inches below the upper water-surface, and the necessary level is maintained by shutters, in frames, about 4 feet apart and resting against the needles; when the needles are raised the shutters fall flat and the pass is entirely open.

The locks are 279 feet in length from gate to gate, with a clear width of 34 feet 6 inches; the head of water on the lower gate-sill being 8 feet 3 inches, and at the upper gate about 18 inches more. These dimensions suffice for the passage of Rhine-boats of 1,000 tons burden. The walls are carried to about 3 feet above water-level. To provide later for the passage of twelve or fourteen vessels linked together, the lower lock-gates can be moved 869 feet further, giving a clear inclusive length of 1,148 feet; while lateral and independent sluices from the upper reach enable this large space to be filled quickly from several points. The canals (which, as stated, have a depth of 8 feet 3 inches) are 66 feet wide at bottom; the banks, faced with stone packing or with cement below water-level, having a slope of 1½ to 1, with a benching 3 feet wide at water-level. The towing-path on the left bank is 13 feet wide throughout. The river itself had to be dredged in several places; while at Frankfort a basaltic reef running diagonally across the stream was removed, a cofferdam being erected around the site of operations.

The cost of the works, £275,000, was defrayed by the government; the town of Frankfort, however, undertaking, upon the completion of the canalization and improvement works on the Main, to provide a large safety harbour above the weir. This has been also duly constructed, forming an inclosure 1,837 feet long and 230 feet wide, with a depth—even when the weir is open—of 8 feet 3 inches. At the north end are cranes, sheds, and all the necessary appliances, together with sidings from the railway. The total length of quays at Frankfort is now nearly 3 miles. The authorized cost of the harbour-works is £315,000, of which £225,000 has been expended in the present works, the balance being available for future extensions.

P. W. B.

Enlargement of Basin, and Construction of Lock and Canal at Oberlahnstein. By H. Wolffram.

(Zeitschrift für Bauwesen, 1886, p. 503.)

The original basin, 807 feet (246 metres) long, and from 210 to 328 feet (64 to 100 metres) broad, was constructed in 1863, and is situated on the right bank of the Rhine, at about ⅜ mile above its confluence with the Lahn. The Nassau State Railway, together with high-level sidings and shoots, skirts the eastern side of the quays, &c., and by this and other lines, large quantities of iron-ore are brought here for shipment. The new works comprise the deepening and enlargement of the old basin, and the construction of a canal and lock forming a communication between the basin and the Lahn, and were undertaken in 1882, not so much with a view to affording increased accommodation for trade, as for providing greater shelter and security for craft during seasons of high flood, or ice-flow, such as occurred in November, 1882, when there was a depth of 10 feet over the tow-path. Under such conditions, a strong current tends to set across the site of these works. To prevent this, a dam connects with the mole, dividing the basin from the Rhine, and is continued parallel with the Rhine until nearing the Lahn. Here it turns at nearly right-angles, and keeping at a short distance from the river, joins the above-mentioned railway embankment near the bridge, thus shutting off the basin, &c., from the Lahn, as where the canal intersects the dam, one of the lock-gates is of sufficient height, and designed to act as a flood-barrier. It is the northern portion of the basin that has been enlarged, thereby increasing the area by more than 2 acres; and, including a portion of the canal at its commencement, 312 feet long and 85 feet broad, which is deeper and wider than the remainder, now affords a total area (at floor-level) of about 8 acres. The entrance from the Rhine is at the same point in the mole as formerly, but is increased from 148 feet to 167 feet in width. This mole is 9 feet 10 inches broad at the top, and with outer and inner slopes of 1½ to 1 and 1 to 1 respectively. Its crest is 5·20 feet above the highest observed flood-level, which occurred on the 28th of November, 1882, and this also is the level of the above-mentioned dam, which forms a continuation of the mole. The fall, as a rule, is from the Rhine to the Lahn, and usually is only about 0·23 foot, although occasionally amounting to 1·48 foot; when, however, from local causes the Lahn is flooded and the Rhine unaffected, there is a fall in the opposite direction, as on the 1st of December, 1885, when it amounted to 2·43 feet.

The canal connecting the Lahn with the basin is, including the lock, 1,590 feet long, and varies from 54 feet 6 inches to 57 feet 9 inches in breadth (except at the end nearest the basin which is wider) at the floor-level (also lock-sill level), the latter being

3·44 feet below the lowest observed water-level, 27th of November, 1884. The slopes of the canal are 1 to 1, and faced with dry stone pitching 1 foot 8 inches thick. The lock is situated in the line of the Lahn arm of the dam, and, on account of the fall occasionally varying in direction, there are two pairs of gates provided at the outer or Lahn end of the lock, opening in opposite directions, and one pair at the inner end, or that nearest the basin, which is constructed to open towards the latter; but by a special arrangement (not described), can also be kept closed while the chamber is being filled by a flow coming from the Lahn.

The pair of gates next to and opening towards the Lahn is of timber, and the top 21·78 feet above lock-sill level, this height being sufficient, as at any level above that, the direction of the current, as observed, has invariably been towards the Lahn; the adjacent pair of gates opening Rhinewards is, however, of wrought-iron, as these also act as floodgates when necessary, and their top is 33·80 feet above sill-level, or 2·52 feet above the highest observed flood. The third pair of gates at the end nearest the basin is of timber; the top is 15·88 feet above sill-level. The wrought-iron gates are each 34 feet 6 inches high, and 12 feet broad, provided with triple sluice-valves worked by lever. The entrance to the lock is 19 feet deep, its breadth 23 feet, and its length between gates 121 feet 4 inches; the sides are of stone laid in hydraulic mortar, with a slope of 1 to 1. A description of the method of construction and the pumping arrangements is given. The works were commenced in June, 1882, and opened for navigation in May, 1885; but the extraordinary low-water level of November, 1884, led later to the basin being dredged out to a depth of 3·54 feet below lock-sill level, or 1·70 foot lower than as originally excavated. Particulars of the various materials used are given, together with their quantities. The amount of excavation was 218,436 cubic yards, and the cost of the whole works £28,000. The Paper is illustrated with various diagrams.

D. G.

Cylindrical Sluice-Gates on the Locks of the Canal du Centre.

By — Fontaine.

(Annales des Ponts et Chaussées, 6th series, vol. xii. p. 248, 4 plates.)

The lengthening of the locks on the Central Canal, from 98½ feet to 126⅓ feet, forms one of the most important recent improvements in the inland waterways of France. The filling and emptying of the locks was formerly accomplished by two siphons, 2¼ feet in diameter, situated in the side walls, and by two openings in each pair of gates, and occupied a little over five minutes. The new locks are filled or emptied in two minutes by means of two cylindrical sluice-gates placed in the masonry; the volume of water in each lockage amounting to 785 cubic yards.

Various forms of cylindrical sluice-gates have been tried on the canal of late years; but they may be classed under two very distinct types, namely, the high cylindrical sluice-gate, and the low one. The former consists of a hollow thin sheet-iron cylinder, open at both ends, and surrounded by water. When the sluice is closed, the top of the cylinder is a little above the highest water-level of the upper pool; and its lower extremity, furnished with a conical ring of cast-iron, fits exactly into another similar conical ring fixed in the masonry of a vertical well at the level of the lower pool. On lifting the cylinder, the circular opening of the well is uncovered, and the two pools are placed in communication. This type of sluice-gate has three important advantages, namely; that in being raised, only the resistance of its own weight and the friction of iron on water have to be overcome; that it is only necessary to raise it a height equal to half the radius of the orifice of the well to provide an equivalent outlet; and that for any given section, a greater head is obtained with a horizontal orifice than with a vertical one. The cylinder is counterpoised by weights, encircling rods inside the cylinder, suspended from chains going round pulleys, leaving only sufficient weight for the cylinder to have a water-tight bearing on the conical ring. The movable cylinder adopted has a height of 9½ feet, an external diameter of 4 feet 9¼ inches, and a thickness of ⅛ inch; and the orifice it opens or closes has a diameter of 4 feet 7 inches. Four radial cast-iron arms brace the conical ring at the bottom, uniting into a nave at the centre, in which an iron rod fits; and a similar arrangement braces the ring at the top of the well, and encircles the iron rod to guide the motion of the cylinder. The cylinder, with the rod at the bottom and a rack at the top, weighs 1 ton 151 lbs.; and it is counterpoised, to within 330 lbs., by two sets of weights. It is lifted by a rack and pinion a height of 1¼ foot, in four to five seconds; and the lock is filled in two minutes. About fifty of these sluice-gates have been made, at a total cost of £62 each. No repairs have been required during the three years the gates have been in operation, and they could be readily effected when necessary. The idea of this type of sluice-gate was suggested by the apparatus established by Mr. de Caligny at the Aubois Lock.[1] The difficulties in securing a perfectly water-tight fit between the two conical rings, and the somewhat high cost for a fall of 8½ feet, have led to the conception of the low cylindrical sluice-gate. This sluice-gate also consists of a fixed and a movable portion. The fixed portion, made entirely of cast-iron, consists of a seat for the cylinder, composed of a ring, 4 feet 7¼ inches in diameter, fixed in the masonry at the top of a well, supporting three upright ribs, which are fastened at their tops to a second ring. A hollow cylinder fixed on the upper ring receives the sluice-gate when lifted, and has a cover bolted to it with a hole, 6 inches in diameter, in its centre, to which a pipe is fitted, passing at its upper end into a circular hole piercing

[1] Minutes of Proceedings Inst. C.E. vol. l. p. 220; and vol. lvi. p. 337.

the roof of the sluice-gate chamber. This pipe surrounds the rod for working the gate, and also affords a passage for the escape of the air. The height of this fixed portion above the sill, exclusive of the cover and pipe, is only 2 feet 10½ inches. The movable portion, or sluice-gate, is a cast-iron cylinder, 1 foot 6½ inches high and 4⅔ feet internal diameter, braced by four radial arms, at the junction of which there is a central hole for the passage of the rod for working the gates. As the vertical pressure of the water is supported by the cover, the movable cylinder is only subjected to lateral pressures which are in equilibrium; and the only force to be overcome in opening the sluice is merely the weight of the cylindrical sluice-gate. The cylinder is guided, in its upward and downward movement for opening and closing the sluice, by a horizontal flange at the top pressing against three vertical flanges projecting ⅓ inch from the inside face of the fixed cylinder, and by a bottom flange sliding along the upright ribs supporting the fixed cylinder. The admission of water when the cylindrical gate is down, is prevented by a little roll of caoutchouc at the bottom, and a band of leather at the top. The sluice-gate, with its rod and rack, weighs about 820 lbs.; and its lift of 1¼ foot is effected by a rack and pinion in twelve to thirteen seconds, with an actual pull, including friction, of 24¼ lbs. The filling or emptying of the lock is accomplished in two minutes, as with the high cylindrical sluice-gate. The low cylindrical sluice-gate is placed in an arched chamber, 7 feet wide, 8½ feet deep, and 8½ feet high to the crown of the arch, situated behind the gate-recess. Two of these low sluice-gates were tried on the Central Canal in 1884, and four more were fixed in 1885, with most satisfactory results. No repairs have been needed; and the leakage, under a head of water of 8⅔ feet, does not exceed 430 cubic feet per gate in twenty-four hours; whereas the most water-tight high gates lose three times more. The cost of a low gate, 4 feet 7 inches in diameter, is only £32, or little over half the cost of a high gate for a fall of 8½ feet. The low gate also possesses other advantages over the high gate, namely: it is less bulky; it is quite sheltered from ice above the locks; by dispensing with a central guide-rod, it leaves the whole section of the well unobstructed; and, lastly, it could be adopted for greater falls with very little increase in cost.

L. V. H.

Drainage of Lake Copais. By G. Richou.

(Le Génie Civil, vol. ix., 1886, pp. 357 and 373, 6 woodcuts.)

Lake Copais, about 12½ miles from Thebes, is situated at the bottom of an enclosed basin, separated from the Negropont Straits by a chain of hills, into which the waters from the northern slopes of Parnassus and Helicon drain. The lake, at its ordinary water-level, is a flat marsh of 62,000 acres, covered with reeds, 310 feet

above the sea-level. Each year the affluents of the basin, which are nearly dry in the hot season, raise the waters of the lake from November, till the level reaches a maximum in April; after which the waters gradually fall, till the lake is nearly dry in October. The waters are drawn off by evaporation and subterranean channels. Evaporation removes annually, on the average, a layer of water 5 feet thick. The bottom of the lake consists of a stratum of impermeable plastic clay, covered with a layer of stiff silt, 6½ to 13 feet thick, formed of a mixture of the mud brought down by the affluents and of the decayed vegetation of the lake, furnishing a soil very rich in nitrogenous salts, and containing phosphates. The alternate flooding of the lake and evaporation of water charged with organic matter cause severe marsh fevers, which reach their height in August, and hardly disappear till the end of October. Accordingly, the drainage of the lake will both restore very fertile land to agriculture, and also put a stop to the marsh fevers which infest the surrounding district within a radius of 10 to 12 miles from the lake. Traces exist of very ancient works for preventing inundations, from the rise of the lake, by a series of wells communicating with a gallery under the bed of the lake for discharging the surplus water into the bay of Kephalari; and evidences have been found of attempts to provide other ways of exit. Within the last forty years more efficient schemes have been proposed; and, finally, the project of Mr. Pochet, a French engineer, was adopted, of which the most important portion has recently been completed. The works comprise drainage canals and irrigation works. There are three drainage canals, namely, the Great Canal, 20½ miles long, bordering the east and south banks of the lake, which will receive the waters of five rivers and other streams flowing into the lake, and will have a maximum capacity of discharge of 163 cubic yards per second; the Melas Canal, on the northern side of the lake, with a discharging capacity of 20 cubic yards; and the Inner Canal, for draining the inner waters, capable of discharging 6½ cubic yards per second. The excavation for the Great Canal is 2,170,000 cubic yards; for the Melas Canal, 204,000 cubic yards; and for the Inner Canal, 418,000 cubic yards. The waters of the lake will be discharged from the drainage canals by leading them, at Karditza, through a cutting and a tunnel, 735 yards long, already opened into Lake Hylicus, whose level will be raised 92 feet, and will overflow across a weir, 164 feet wide, and through cuttings and a tunnel into Lake Paralimni, whose level will be raised 55¾ feet; and the surplus waters will flow thence into the sea through a tunnel at Anthedon, 940 yards long, preceded by a cutting, 365 yards long, and followed by another, 268 yards in length. The two cuttings had been completed, and the tunnel was to be finished by the end of the year (1886); and the whole of the works for discharging the waters will be ready to carry off the floods of this winter, so that a large portion of the outskirts of the lake, amounting to from 10,000 to 12,000 acres, has its drainage already provided, and can be at once cultivated. As the streams flowing into

the lake have, for the most part, a very small discharge in the dry hot summer season, provision for irrigation forms an essential element in the scheme, and was the reason for carrying the course of discharge through the small lakes instead of direct to the sea. The lake of Hylicus, or Likeri, has been chosen for the sole reservoir, as the raising of the waters of Lake Paralimni to the necessary level, though it would have dispensed with the Anthedon tunnel, would have involved an increased cost in the purchase of land bordering the lake, and the extension of the irrigation canal. Accordingly, the maximum water-level of Likeri has been fixed at 230 feet above the sea, whilst that of Paralimni will be only 148 feet above sea-level. Two cuttings, having a total length of 1,785 yards, with a tunnel, 1,124 yards long, under the Hungara Pass, connect the two lakes, and lead the water to hydraulic machinery, which will raise $5\frac{1}{4}$ cubic yards of water per second in summer for the purposes of irrigation. The exact course of the irrigation canal, which will receive and distribute this water, has not yet been determined; but the canal will have a length of about 28 miles, and an average slope of 1 in 5,000. The minimum discharge of the river Melas will provide an additional volume of water of $2\frac{2}{3}$ cubic yards per second for irrigation, which will make the total volume nearly 8 cubic yards, and will serve 25,000 acres, without taking into account the waters of the Cephissus. The works were commenced in 1882; it is estimated that about three more years will be required for the completion of the drainage of the whole area of 62,000 acres; and the water was admitted into the Karditza cuttings and tunnel last June. The works have been impeded by the malaria, which stops operations for about four months in the year, and by the dearth of materials and labour in the district.

L. V. H.

Wilhelmshaven Dockyard Extension Works.

By — Kayser.

(Deutsche Bauzeitung, 1886, pp. 541–546.)

This extension became necessary when, after the Franco-German war, Wilhelmshaven became an Imperial instead of a Prussian naval station. The works then existing had been fifteen years in progress, and were opened in 1869 by the King himself with much ceremony. They consisted of:—

The harbour[1] entrance confined between two parallel moles, and comprising a basin 690 feet long and over 300 feet wide.

The outer harbour (*Vorhafen*) 600 feet long by 410 feet wide.

The harbour canal, 1,230 yards long and 275 feet wide at normal water-level, connecting the outer with

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[1] Minutes of Proceedings Inst. C.E. vol. lxiv. pp. 378–380.

The inner harbour or dockyard basin, of sufficient capacity to berth twelve large war-ships: connected with it on the west side are three dry-docks and two slips, and in the north-west corner a small harbour for gunboats.

The small harbour for dredges and barges, on the north side of the harbour canal and connected with it.

The extension works, described in Mr. Kayser's Paper, were commenced in 1875, and were recently formally opened by the Chief of the Admiralty. They comprise:—

(*a*) A fitting-out basin formed by widening a portion of the harbour canal on its north side.

(*b*) A new harbour entrance confined between moles, and connected by a tidal sluice chamber to the

(*c*) Junction canal, which is separated from the fitting-out basin by a pontoon head, which carries a roadway and rails leading to the coal stores and the old entrance to the harbour.

(*d*) A harbour for merchant vessels between the Junction canal and the Ems-Jade canal, and connected with it on the south side, a harbour for dredges and barges, a dry-dock and a slip.

The works also comprised the formation of a temporary harbour for merchant ships while the new sea dyke was being built across their old anchorage ground, and the construction of small harbours for torpedo and gun-boats respectively.

The basins are surrounded by quay-walls on concrete foundations, the walls themselves being of hard burnt brick with granite coping.

The north and south moles protecting the new harbour entrance are 650 and 150 yards long respectively, and are laid on concrete block foundations—each block measuring 1·4 metre high, 1·5 metre wide, and 3 metres long, or in volume 8¼ cubic yards, and weighing over 12 tons: the distance between the moles in a straight line is 230 feet.

The sluice chamber is 574 feet long with a clear width of 78 feet 8 inches, and depth of water to the sill of 30 feet 6 in. At the outer or sea end are three pairs of gates, and at the inner end it can be closed by a pontoon.

The longest German ironclad, the "König Wilhelm," is 356 feet between perpendiculars, and draws 25½ feet of water; and the widest ship, the "Kaiser" is 62 feet 4 inches wide—the sluice chamber, therefore is, of ample capacity for present requirements.

The extension works involved:—

4,218,500	cubic yards of	earthwork.
83,200	„	concrete.
156,000	„	brick masonry.
11,960	„	granite.

A plan of the works accompanies the paper, showing the works executed before 1870, and the subsequent extension, the latter being distinguished by line shading.

W. H. E.

Dredging-Pontoon with Drum-Valve.

(Centralblatt der Bauverwaltung, 1886, p. 309.)

This is an improved arrangement for discharging the contents of barges or pontoons, designed by the Author for use at Brieg on the Oder. Instead of the opening at the bottom of the vessel being closed by a plate flap, hinged downwards, a circular drum-shaped vessel covers the space, working upwards or downwards in a cylindrical casing carried on four gussets in the centre of the hopper or vessel containing the sand, mud or material to be disposed of. The drum, which has openings for the easy passage of the water, is raised by a bar worked by a lever turned through 180°. The vessels carry two inverted conical hoppers, 9 feet 10½ inches in diameter at top, and capable of taking between them about 13 cubic yards of material. The lift of the valve is 1 foot, and diameter of opening 2 feet. With these dimensions the contents are discharged in six minutes; but with an orifice of 2 feet 8 inches, and lift of 1 foot 2¼ inches, as originally proposed, this would be done in half the time. The vessel draws 2 feet 8 inches of water.

P. W. B.

Work done for the Preservation of Holyoke Dam, Mass.

By C. Herschel.

(Transactions of the American Society of Civil Engineers, vol. xv. pp. 543–580, 10 plates, 8 photographic views.)

The first dam at Holyoke on the Connecticut river, intended only to be a temporary work, was swept away in November 1848 before it was finished. In 1849 the second dam was made which forms practically the inner half of the present structure. It is made of timber, is ⅕ mile long, and has abutments of masonry at each end. The up-stream slope has a batter of 2½ to 1, and on the down-stream side there was a nearly vertical drop of 30 feet from the crest to the rock. The timbers are bolted to the solid rock by some three thousand 1¼-inch bolts. The interior of the timber cribwork between the inner slope and the down-stream face was filled for some 10 feet above the rock with stone. The inner toe was protected by concrete, and the lower portion of the inner slope was covered with gravel; the crest was protected by boiler-plate. The total available fall is 40 feet, and canals at three different levels are supplied. The total cost was £30,000, equivalent to £50,000 now. The river on one occasion ran 12 feet deep over the crest, but about 9 feet is usual in a freshet. The Holyoke is the highest overfall-dam in the world. The work stood unchanged from 1849 to 1868, when it was found that the falling

water had scooped out a large hole at the outer toe, and had even undermined the timber-work. The strata of the rock foundation dip about 30° to the horizontal down-stream, which naturally favours erosion. The timber-work of the down-stream face had been much injured by blows from floating logs of wood, the same floating log being frequently projected several times against the work by the eddies and impact of the falling water. A down-stream slope of timber was now added, the addition of this new work making the sectional area more than double the original size. The new work was made of round logs formed into perpendicular cribs; these were filled with stones, some of the stones weighing from 4 to 5 tons, and the whole was planked over. The cost of this is given at from £53,000 to £70,000. It is successful in protecting the old work, and in preventing fresh undermining, but there is again a pool 20 to 25 feet deep on the down-stream side of the new work. For another ten years the dam stood well, but from 1879 onwards the plank covering of the inner slope has given way in places, and the leaks so caused have been repaired by means of wooden cribs floated and sunk over the leak. The bottom edges of these cribs were bevelled to suit the inner slope, their size has gradually increased, and the method of applying them has gradually improved. In order to clear the slope so that the crib may rest on it, dredging and the water-jet were applied. There was a good deal of trouble connected with this, as at the time of the 1868 additions large stones, which had been brought for the new work, had been carelessly dropped on the up-stream slope. When the crib rested on any of these, there was a tendency to make a fresh hole in the planked surface. Sheet-planking had frequently to be driven outside the cribs into the gravel deposit. In making the crib tight, bags of gravel were preferred to bags of clay, the latter melting out. The water inside the crib quickly leaked away through the dam itself, the work being always above the level of the river below. The crib used in 1884 was 45 feet long by 40 feet wide; but this was not large enough for one leak, and a smaller crib was sunk by its side.

It was necessary, however, to do something more than merely patch up leaks as they occurred. The leaks might go on increasing, the whole water might be lost, and the mills, with an invested capital of £2,400,000, be stopped. At first an attempt was made to fill gravel under the planking of the inner slope. To do this, cribs were sunk, the planking was cut through, gravel tipped in, and jets of water were applied to force the gravel into all the vacant spaces. In 1885 it was determined to repair the dam in the following manner. A continuous row of 3-inch sheet-piling was to be driven, not plumb, but square to the inner slope, and some little distance down it, from one abutment to the other, into the original stone filling of 1849, and resting at the top on one line of the original longitudinal timbers. Then puddled gravel was to be filled in on each side of the sheet-piling. In order to carry this out, floating coffers were used by which 100 feet in length of the inner slope

of the dam could be exposed at one time, and 20 feet of the planking down from the crest removed. The side coffers were vertical boxes with bevelled bases, but the front coffers were triangular in cross-section, strutted and planked. Both were weighted with stone when over their proper places. The slope was cleared mainly by an under-water scraper, worked from an anchored barge by aid of a snatch-block fastened to the crest of the dam. Divers were required, and their work was somewhat perilous through the imperfect condition of the planking. The coffers allowed for a depth of 4 feet flowing over the crest, but one freshet was 4½ feet, and could with difficulty be controlled. After the coffers had been brought into place and sunk, the interior emptied itself downstream, carpenters removed the old planking, the sheet-piling was driven, and the gravel filled in. The gravel was brought from 2 miles distance up the river, and 12,900 cubic yards were put in at an average rate of 200 cubic yards per diem, costing just 2*s.* per cubic yard for wages. The gravel was forced into place by "hydraulicking" from holes tapped in the dam, by the natural leakage through the dam, and by the occasional removal of a top plank somewhere so as to cause a cascade. The coffers were then unloaded carefully, and floated into another position. The dam is now quite safe, for even if all the planking below the tops of the sheet-piling were to decay, the gravel hearting would remain firm. It was expected originally that the leakage of water through the dam would keep the timber from rotting, but the plank covering was found decayed in places, the decay having worked upwards from below. The square ends of timbers rotted so as to leave the solid part of a rounded form. All timber within 20 feet of the crest showing signs of decay was taken out and replaced by new. The leakage has been very much decreased by the quantity of gravel. The cost of recent works has been £13,000, including plant. Among the lessons learnt from this dam are the following, namely: that a wooden dam should never be left hollow, nor should it be filled with stone. A row of sheet-piling should be driven, and gravel, not stone, filled in, for stone filling will not prevent decay, while timber surrounded with gravel will last indefinitely. The Author concludes with some remarks upon his design for a stone dam for this site, and points out the importance of a water-cushion to prevent erosion under the fall.

J. G. G.

Dam on the Schuylkill, Philadelphia. By Fred Graff.

(Proceedings of the Engineers' Club of Philadelphia, vol. v. pp. 372–378, 3 plates.)

The Author gives a short history of the additions to and repairs of the Fairmount dam on the River Schuylkill. This dam gives a fall at high tide of nearly 8 feet, and at low tide of 14 feet, available as power, which is used to pump water up for the supply of

Philadelphia. The history includes that of works done from the year 1811 to 1873, and gives an account of the various proposals originally made besides the one actually adopted, and tells how various timber cribwork dams were from time to time built on top of or in front of one another, the breadth of cribwork in the present dam being over 90 feet. The total length of the overfall is 1,112 feet, rather more than half of which is founded on rock and the rest on cribwork. The present profile of this weir is as follows. On the inside a long flat slope of about 12 horizontally to 1 vertically, consisting of earth-backing resting on cribwork; on the crest there is 12 feet level; on the downstream side there is first a planked slope of about 4 to 1 for 16 feet, then a vertical drop of 6 feet, then another planked slope of 10 to 1 for 20 feet, after which the face is vertical. There is a depth of nearly 25 feet at low-water immediately below the dam. The slopes on the down-stream side tend to project forcibly away from the work timber and other matter that may be floating down. A scheme to build a masonry dam instead of this cribwork one was abandoned for want of funds.

J. G. G.

Water for the Manufactories of Verviers.

By T. Verstraeten.

(Annales de l'Association des Ingénieurs sortis des écoles spéciales de Gand, vol. ix. 1886, pp. 121–135, 2 plates.)

Verviers is the seat of the principal cloth manufactories of Belgium. Until the year 1830 the water of the river Vesdre had sufficed for the wants of the manufacturers; but about this time the Belgian Government drained the marshes in the upper valleys of the river, and in consequence the flow of the Vesdre became insufficient.

After much delay and considerable discussion of various projects, a massive masonry dam was built across the river Gileppe,[1] intercepting water from a catchment-area of 16 square miles, and forming a reservoir capable of holding 2,700,000,000 gallons. The Government, having by its drainage works interfered with the discharge of the river, agreed to pay for the masonry dam and its sluice-passages. There still remained the aqueduct to Verviers and distribution in the town. All efforts to form a private company to carry out the remaining works failed, and the town, driven into a corner, undertook the heavy responsibility.

The masonry dam was finished in 1875, and the whole was in working order in 1878; it may thus be seen how far anticipation was justified by the result.

Observation had shown that during a period of five hundred and forty days in 1865 and 1866 the average daily discharge of the

[1] Minutes of Proceedings Inst. C.E. vol. xlviii. p. 312, and vol. lvi. p. 337.

Gileppe valley above the site of the dam was 8,300,000 gallons. If it be assumed that the regulating action of the reservoir can be spread over five hundred and forty days, then of this quantity 2,000,000 gallons had to be given as compensation-water to the Vesdre, and 400,000 gallons was the anticipated loss by evaporation (assuming $\frac{1}{10}$th of an inch per diem over the water area), leaving less than 6,000,000 gallons for the supply of the town. If however five hundred and forty days is too long a period, then the available daily supply would be reduced; for example, the average daily flow of the Gileppe during a period of two hundred and fifty days in 1865 only amounted to 3,000,000 gallons (the absolutely lowest daily flow was 266,000 gallons).

In former years the manufactories of Verviers had been accustomed to a daily supply of 13,000,000 gallons, but during the summer months of the rainy years 1881 and 1882 they could scarcely get 11,000,000; and during the month of October 1883, an average of only 5,000,000 gallons per diem was taken from the reservoir, and no compensation-water was given to the Vesdre.

The chemical analysis of the water in 1878 gave 2·1 grains of solid matter in the gallon, of which 0·8 grain was organic. In July 1883, a total of 3·6 grains in the gallon was obtained, of which 1·1 grain was organic. Considering that the catchment-area is not inhabited, this organic matter must be almost entirely of vegetable origin.

The cost of the dam and sluice passages executed by Government was £199,000. The aqueduct to and distribution in the town, together with interest on capital during progress, cost £361,000, making a total expenditure of £560,000. If interest at 4½ per cent. be assumed, and the annual charge for maintenance be taken at £2,660, there results the sum of £27,860 as the annual charge to Government and town for the Gileppe water. Taking the average daily consumption during the summer of 1883, which was 7,600,000 gallons, each thousand gallons cost 2·4*d.* By way of comparison it may be noted that this is exactly the cost of each thousand gallons supplied to the town of Brussels during the year 1883.

In regard to the sale of the water, during the year 1884 manufacturers paid from 0·9*d.* to 2·2*d.* per 1,000 gallons, and private consumers paid 6*d.* per 1,000 gallons. At Brussels, where the water is nearly all used for household purposes, the charge is 9·5*d.* The quantity of water purchased since the works were completed has amounted to a daily average of over 5,000,000 gallons, being at the rate of 77 gallons per head of the population, of which only 3 gallons were sold for household purposes. The small quantity sold for household purposes is accounted for by the prevailing use of private wells and cisterns.

It is clear that the works are not sufficient, and investigations are now being made as to the best way of further increasing the supply.

In reference to the financial aspect of the works it may be noticed that the net receipts, after deducting expenses of mainten-

ance, would not pay quite 2 per cent. interest on the capital expended. Consequently, although the works have had excellent indirect results, and have saved the cloth manufactories of Verviers from ruin, yet (at any rate with the prices now charged) they could not have been carried out by private enterprise alone.

J. G. G.

Rainfall on the Water-Sheds of Sudbury River, and Cochituate and Mystic Lakes, U.S. By D. Brackett.

(Journal of the Association of Engineering Societies, 1886, p. 395.)

The drainage slopes of the Sudbury River, covering an area of 76 square miles, are generally steep, and are not highly cultivated. Lake Cochituate has a drainage-area 18·87 square miles, generally flatter than the Sudbury River district. The watershed of Mystic Lake, 27¾ square miles, is very similar to that of the Sudbury River, mostly sand and gravel on rock.

The general results of observations taken for twenty-three years, ending 1885, for Lake Cochituate; eight years for Mystic Lake, and eleven years for Sudbury River, give the following averages:—

Rainfall.

District.	June to November inclusive.		December to May inclusive.	
	Rainfall.	Rainfall collected.	Rainfall.	Rainfall collected.
	Inches.	Inches.	Inches.	Inches.
Lake Cochituate . . .	21·37	3·91	21·08	13·45
Sudbury River . . .	21·613	3·693	22·353	16·557
Mystic Lake	19·59	3·66	21·03	13·30
Averages	20·858	3·754	21·488	14·436

From an inspection of the illustrative profiles presented by plotting the annual rainfalls, it appears that from the 1st of July to the 1st of November, the percentage of rainfall which can be collected is very small. The month of September is generally one of small rainfall; whilst a very large proportion of the annual rainfall is collected in February, March, and April. The average monthly volume collected is equal to about 1½ inch; the volume is less during seven months, and is only about ½ inch monthly during four months. The years 1880 and 1883 were years of small rainfall, and of small percentage of collection, 33 per cent. The collection in streams and ponds was only between 10 and 11 inches.

D. K. C.

Spontaneous Evaporation. By D. FitzGerald.

(Transactions of the American Society of Civil Engineers, 1886, p. 581.)

By the permission of the Boston (U.S.) Water Board, Mr. FitzGerald was enabled to prosecute an extensive course of experiments on the natural or spontaneous evaporation from water-surfaces. Three evaporating pans, 14·85 inches in diameter, in which 1 oz. of water occupied 0·01 inch in depth, were placed immediately over tanks which were supplied with hot water at different temperatures, supplied from a steam boiler. The pans could be slightly raised when required in order to be weighed.

The floating tanks also were placed in the middle of the Chestnut Hill Reservoir, of the City of Boston water-supply, where the water was 20 feet deep. A large raft floated the tanks, and it was moored at one end to an anchor around which it could swing freely with the wind. One tank was of wood covered with copper, 2 feet square, with 1½ foot depth of water. The other was a plain tin vessel, 12 inches in diameter, 2 feet deep.

With respect to the influence of variations of barometric pressure, it was so slight that it was disregarded in so far as the rate of evaporation was concerned.

The depth of water had no other influence on evaporation than as it affected the temperature of the surface. The general result of the observations was to lead to a close scrutiny of the temperatures of the evaporating surfaces, of the force of vapour in the air, and of the velocity of the wind: these were found to be the three important factors.

It became evident that the maximum evaporations were not recorded on the hottest days in the year. On a cold day, preceded by warm weather, maximum evaporation might be expected. On the 23rd of June, 1885, the greatest evaporation recorded occurred at Chestnut Hill Reservoir, namely, 0·57 inch from Tank No. 1, 0·64 inch from Tank No. 2, and 0·58 inch from Tank No. 3. The mean temperature of the water in the reservoir was 70°·7 Fahrenheit; in Tank No. 1, 69°·8; in No. 2, 70°·8; in No. 3, 69°·9. The mean temperature of the air was 60°·2, about 10° less than on the preceding days. The pressure of vapour in the air was only 0·313 inch. The velocity of the wind at 30 feet above the water averaged 12·3 miles per hour. The average daily evaporation in Arles, France, is quoted from the results of Mr. Salle's experiments, as 0·56 inch on the 31st of July, 1878.

On the 19th of December, 1885, the atmospheric temperature was 12° Fahrenheit, or 20° below freezing-point. The temperature of the water at the surface, and at a depth of 10 feet, had been 38° for some time, owing to warm weather, and it was now 37°. The tension of the vapour in the air was equal to 0·03 inch. The wind was blowing at the surface at the rate of at least 4 miles per hour. The rate of evaporation was about 0·23 inch per day. This case,

though very unusual, is opposed to the usual assumption that evaporation in the winter months should be valued at nothing.

It was demonstrated that the evaporation from a large water-surface was nearly alike by day and by night; and that the evaporation from a considerable body of water may be greater on some particular days, even during midsummer, than from a shallow pool.

In answer to the question, "What is the highest temperature that the surface of a reservoir ever attains?" it is stated that at 5 P.M. on the 18th of July, 1885, the temperature of the water in Chestnut Hill Reservoir, was:—

	Fahrenheit. °
At the surface	82·2
And at a depth of 5 feet	82·2
" 7 "	80·5
" 8 "	79·0
" 9 "	77·5
" 10 "	76·0
At the surface, on the 10th of September, 1884	86·0

The last observation was made during extraordinary heat, when the water in a copper rain-gauge, covered, was at 116° Fahrenheit.

The following Table shows, in the 2nd column, the experimental values of the evaporation for each month of the year in inches of water. Reducing these values into a mean curve, the corrected values are those in the 3rd column; and the proportions per cent. of the total evaporation are given in the last column:—

Month.	Observed Evaporation.	Mean Evaporation.	Per cent. of Total Evaporation.
	Inches.	Inches.	Per cent.
January	0·90	0·98	2·51
February	1·20	1·01	2·58
March	1·80	1·45	3·71
April	3·10	2·39	6·11
May	4·61	3·82	9·76
June	5·86	5·34	13·65
July	6·28	6·21	15·87
August	5·49	5·97	15·26
September	4·09	4·86	12·42
October	2·95	3·47	8·87
November	1·63	2·24	5·73
December	1·20	1·38	3·53
Totals	39·11	39·12	100·00

From this Table it appears that the total evaporation for the year was about 39 inches of water; and that the maximum evaporation took place in July, and the minimum in January, evaporation taking place during even the coldest months.

D. K. C.

A Continuous Self-acting Air-Tester.

By Professor Dr. A. Wolpert, of Nuremberg.

(Gesundheits-Ingenieur, 1886, p. 713.)

The Author draws attention to the pocket air-testing apparatus constructed by him in 1882,[1] which, as is the case with all similar contrivances, required that certain manipulations and measurements should be undertaken. These, although they were simple and readily capable of being carried out, stood somewhat in the way of the general adoption of the apparatus, and he therefore attempted to discover some plan by which the amount of carbonic acid gas present in the atmosphere could be seen at a glance. The apparatus he now employs consists of a piece of thin thread or string, having wool spun over it, which cord, owing to its having been repeatedly dipped in a solution of phenolphtaleïn, has become tolerably stiff; this is placed in connection, at the upper extremity, with a small glass funnel, into which a weak solution of crystallized soda, tinted with phenolphtaleïn dissolved in alcohol, is permitted to drop from a small siphon. This siphon, which is made of capillary glass tubing, is made fast to a hollow metal float, which forms the cover of a shallow vessel containing the red fluid. In order to preserve this solution free from contact with the atmosphere, it is covered with a thin coating of some non-volatile and inodorous mineral oil. The float, in the form of an inverted cone, is constructed of thin nickel-plated brass, and the shape has been chosen in order to prevent air-bubbles in the test-liquid from adhering to it. The solution passes over by the siphon at a very slow rate, and in ordinary apartments it has been found that a speed of one drop per one hundred seconds serves to keep the cord moist. The cord is 40 centimetres in length, and is provided at the lower end with a small pan to receive the superfluous liquid. This little receptacle will require to be emptied once in every twenty-four hours; the supply in the upper vessel is calculated to last for a month, and is a very cheap and readily-made solution. The cord is stained a deep red by the liquid, but is bleached by carbonic acid in the atmosphere, and the colour is deepest at the upper end on which the drop descends, and becomes gradually paler, and eventually fades out entirely at the lower extremity, in an atmosphere which contains only the normal amount of carbonic acid gas, which, as with all similar contrivances, is made the index of the degree of pollution. It thus becomes possible, on a slip of paper behind the cord, to indicate approximately the purity of the atmosphere, as shown by the tint of the cord; the higher the discoloration extends, the worse must be the atmosphere, and after careful experiment the Author is able to denote on the scale the

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[1] Minutes of Proceedings Inst. C.E. vol. lxxxiii. p. 551.

proportions of carbonic acid gas present from 0·7 per 1,000 volumes, when the air is regarded as pure, up to from 4 to 7 parts per 1,000, when it must be considered to be extremely bad; the intermediate proportions from 0·7 to 7 may by subdivision be indicated with a fair amount of accuracy.

G. R. R.

Fifty-ninth Meeting of German Naturalists and Physicians. Water Filtration. By Dr. Plagge of Berlin.

(Gesundheits-Ingenieur, 1886, p. 608.)

The Author communicated the result of a series of tests undertaken by him with various kinds of filters at the Berlin Hygienic Institute, in the presence of representatives of the makers, the conditions laid down being that the filtered waters must be rendered free from micro-organisms. The various kinds of filters tested were:—1. The spongy-iron filter of Dr. Bischoff; 2. Various forms of carbon filters; 3. Stone and gravel filters; 4. Paper filters, specially those of Enzinger of Worms, and of Arnold and Schirmer of Berlin; 5. Clay filters, including those of Dr. Chamberland of Paris, Olschewsky of Berlin, and Dr. Hesse of Schwarzenberg; 6. Asbestos filters, as constructed by Breyer of Vienna, and experimental filters made by Dr. Hesse and Messrs. Arnold and Schirmer. Spree water was used for all the trials, and with spongy iron it was found that the water in passing through the filter became saturated with soluble salts of iron, which subsequently rendered the filtered liquid turbid. Steps have been taken by Dr. Bischoff to counteract this defect. The water was tested by Koch's process, and while the river water contained in 1 cubic centimetre 38,000 colonies of bacteria, the same volume of the filtered water yielded 18,000 to 24,000 colonies. This result, proving the spongy-iron filter incapable of retaining germs, was said to have greatly astonished the inventor, who wished to present an altered form of apparatus. The previous experiments of Lewin gave similar results, and the amended filter has not been sent in. 2. Though the carbon filters in this group were of many different kinds, they varied but little in the construction of the essential part, which was in all cases a block of porous carbon through which the water is made to pass. Using the town supply, which before entering the filter contained 68 germs in 1 cubic centimetre, a similar volume of filtered water contained 12,000 germs; so that not only was the filter unable to keep back the micro-organisms, but it proved itself to be a most fertile breeding ground for bacteria. A contrivance was employed for giving a second filtration to the effluent, and, after removing this, the fluid contained only 1,000 germs per cubic centimetre, the filtration being better without it than with it. Even after the filtering

material had been sterilized by means of a 5-per cent. solution of carbolic acid, the filter always, after the lapse of a day or two, rendered water more impure than it had been previous to filtration. 3. Various filters constructed of gravel and sand proved ineffectual to retain the germs. 4. Paper filters. The filter of Enzinger, which contained sheets of compressed cellulose, gave a copious supply of filtered liquid; at a pressure of 1¾ atmosphere the yield was 12 litres per minute, and at a lower pressure the filter passed ½ litre per minute. The bacteriological examination showed that when Spree water, containing 40,000 colonies per cubic centimetre was used, the high-pressure filtrate yielded 8,000 colonies, and the low-pressure filtered water 4,000 colonies in the cubic centimetre. In the filter of Arnold and Schirmer, which was also composed of sheets of compressed cellulose, the results as to rapidity of yield were very satisfactory; but this filter also proved incapable of keeping back the germs, and prolonged filtration gave gradually worse results. 5. Clay filters, constructed by Chamberland on the principle suggested by Pasteur, succeeded surprisingly well. Tested with water from the mains which contained 284 colonies in the cubic centimetre, the filtered liquid produced only 4 colonies, which might readily have dropped in accidentally from the atmosphere; the result the second day was equally good, but under protracted use the filtered water no longer remained germ-free. Dr. Hesse's filter, though passing a smaller volume of water, was equally good to that of Chamberland. Olschewsky's filter, while capable at first of yielding a filtrate free from germs, did not stand a protracted test. All the filters of burnt clay permit the germs to grow through them in course of time. 6. Asbestos filters. The filter of Dr. Hesse could not be tested as it is not yet put upon the market. Arnold and Schirmer's asbestos filter will retain the germs for awhile, but will not stand a lengthy test. Breyer's micro-membrane filter gives an ample yield under low-pressure, and produces a filtered liquid free from germs, but will not do so for any length of time. In the case of asbestos filters it must be remembered that the cheapness of the filter-plates renders frequent renewal of the filtering material possible. The Author states that the result of the experiments demonstrates that spongy iron, carbon, sand and gravel, and paper, are by no means reliable filtering materials; that burnt clay and asbestos produce for a short time thoroughly good results, but that the micro-organisms grow through them in the course of a day or two. In spite of the negative results, it is satisfactory to possess a trustworthy method of testing filters, and to be in a position to exclude a number of useless and even injurious contrivances.

G. R. R.

New Automatic Flushing-Siphon on Picker's System.

(Gesundheits-Ingenieur, 1886, p. 577.)

The various methods of flushing drains are reviewed, and mention is made of the annular siphon, the tipping-trough, and the siphon exhausted by means of an injector, worked from the town water-mains. This last plan is costly, and all the contrivances described are liable to be stopped up by solid matters contained in the sewage water. By reference to diagrams the system adopted by Picker is explained. The inventor employs an annular siphon set in a chamber of brick or masonry. The inner tube has a turned lip at the top, and dips at the foot into a metal dish with a raised centre, sunk a few inches below the bottom of the sewer. The exterior tube of the siphon is raised slightly by means of stilts above the floor of the flushing-chamber; the upper extremity is bell-shaped, and is perforated with a small orifice at the top, which is capable of being opened or closed by a ball-cock, the lever-arm of which is controlled by a ball-float at the same level. When the flushing-chamber fills, the water rises in the outer tube of the siphon, and as the aperture is closed the air in the smaller limb, and in the upper part of the siphon-tube becomes somewhat compressed, and the level of the liquid in the flushing-chamber may rise considerably above the top of the inner tube. But when this takes place, the lever ball-float is raised, thus opening the air-way and permitting the compressed air to rush out. The water rapidly passes in to take its place, rises above the top of the inner limb in so doing, and thus produces a down rush; but the water-level in the chamber at once sinks, causing the air-inlet ball-valve to close, and the operation of the siphon speedily empties the chamber. When the accumulated water has nearly all passed away, a second ball-tap, near the bottom of the chamber, is brought into action; it drops, failing the support of the water, opens the air-inlet at the top of the siphon, and stops the discharge. As soon as water again begins to collect, the lower ball-float rises and closes the air-inlet, and the gradual rise of the water compresses the air within the siphon as before, till the level is reached at which the upper float is raised, and the compressed air within the siphon is allowed to escape as at first. The apparatus is very simple, all the movable parts are under cover and above the level of the sewage-water; the action of the siphon is absolutely automatic, and it makes no difference whether the supply is continuous or consists only of the periodical discharges of domestic waste-water.

G. R. R.

New Constructions of High-Speed Engines. By Dr. Proell.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, 1886, p. 190.)

To the development of high-speed steam-engines electric lighting has to a great extent contributed. To obtain greater power at lower prices, the tendency has been to increase the number of revolutions; generally speaking, this has been effected at a sacrifice as regards economy, but the Author is of opinion that with accurate workmanship and a not too high speed, economy in steam may be attained by a suitable construction; after describing the Porter-Allen high-speed engine,[1] he proceeds to describe a system of his own, which he considers to be simpler and better than the Porter-Allen.

In place of four flat balanced slide-valves, as used in the Porter-Allen engine, a cylindrical oscillating valve is employed, placed below the cylinder. The axis of the valve is at right-angles with that of the cylinder. The steam passes through the inside of the valve; the ports are in that part of the surface furthest from the cylinder. The weight of the valve rests on the wearing-surface, and all the lubricant from the cylinder flows to it down the steam-passages. In consequence of the low position of the valve, the condensed water runs off from the cylinder of itself. To ensure sufficient admission-area with an early cut-off, there are two passages in the valve by which the steam can enter. Motion is given through a crank attached to the valve-spindle by an eccentric-rod. Instead of the curved link of the Porter-Allen engine a straight bolt is used, on which the block connected with the eccentric-rod slides. In order to obtain a constant lead for various degrees of expansion, a double motion is employed, both the rod and the eccentric strap being adjusted by the governor.

A special construction of governor of the Author's design is also used; it is of the inverted type, a spring taking the place of the counter-weight in ordinary governors; the distinctive feature consists in the fact of the proportions being so arranged that the balls always move approximately in a plane at right-angles to the governor-spindle, so that when the latter is vertical no work is performed by the weight of the balls. The action is approximately astatic, as is mathematically demonstrated in the original. In the larger machines of this type, a longitudinal reciprocating motion is imparted to the valve, not synchronous with the oscillations of the latter. This makes the wear very uniform, prevents grooving, and reduces the friction, thus rendering easier the work of the governor.

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[1] "Engineering," February 1879.

After a short description and criticism of the Armington-Sims high-speed engine, the Author proceeds to describe some improvements of his own in this type of motor. In place of the piston-valve used in the engine named, he substitutes an oscillating valve similar to that already described. The governor of the Armington-Sims engine is centrifugal, and the arms are pivoted to those of the fly-wheel, or to a separate disk keyed to the fly-wheel shaft; they work against two springs, and actuate two eccentric disks, one moving within the other. The Author's improvements consist in the substitution of one spring and one movable disk respectively, instead of two, the spring being so placed that the effect of the centrifugal force on it does not influence the governor; the latter is very powerful. The Author's engines run at from 180 to 400 revolutions per minute. No particulars as regards experimental economy are given. The original is illustrated by a plate and several wood-cuts.

G. R. B.

Disincrustation of Belleville Boilers. By C. Quéhant.

(Annuaire de l'Association des Ingénieurs sortis de l'École de Liége; July, August, 1886, p. 319.)

For the prevention of incrustation in Belleville tubulous boilers sheet-zinc has been successfully used at Liége, where the waters are calcareous and selenitic. Three sheets of No. 18 zinc, 6·56 feet by 30 inches, weighing together about 100 lbs., are each cut up lengthwise into twenty-four bands or strips, which are rolled into helical form, and introduced into the water-pipes of the boiler after these have been cleaned out. A new metallic surface of about 100 square feet is thus presented for receiving the deposit, which takes to it by preference, and coats it for a thickness of at least $\frac{1}{25}$ inch; often much thicker. The boilers, besides, appear to be impressed with an incessant reciprocating movement, by which deposit is prevented from forming on the tubes. The tartar in suspension is easily removed at each discharge. The boiler is only cleaned out once in five weeks, the cost of which, with the renewal of the zinc, is as follows:—

	£.	s.	d.
100 lbs. of zinc at £20 3s. per ton . . .	0	18	0
Labour to form helices	0	3	2
Do. cleaning, two days	0	7	11
Mastic	0	2	1½
	£1	11	2½

For one year, eleven operations, the cost amounts to £17 3s. 3½*d.*

The composition of the white coating, found on the tubes after five weeks of work, is as follows:—

	Per cent.
Oxide of zinc	37·15
Peroxide of iron	0·35
Lime	20·66
Magnesia	2·24
Sulphuric acid	31·48
Silica	1·60
Carbonic acid, water, and organic matter	6·45
Total	99·93

D. K. C.

The Causes of Violent Explosions of Steam-Boilers, and Boilers Heated by Steam. J. HOCHEREAU.

(Moniteur Industriel, 17 Feb. 1887.)

In this Paper the Author first examines the evidence which exists as to the occurrence of detonations, or very violent explosions in steam-boilers, and comes to the conclusion that the cause is the presence of air and hydrogen, more or less carburetted with the steam; that boilers fed with water contaminated with organic impurities, and especially fatty matters, are most liable to such accidents, because the impurities being decomposed yield the dangerous gases in question, and are fired by electric sparks generated by the friction of steam passing through narrow passages. The Paper concludes by a notice of the rapidity and intensity with which shocks are transmitted by water.

W. A.

Occurrence of Petroleum in India.

By H. B. MEDLICOTT and R. A. TOWNSEND.

(Records of the Geological Survey of India, vol. xix. 1886, p. 185 and p. 204.)

All the petroleum of India occurs in middle or lower tertiary rocks, as in Galicia and at Baku. Within the Rawalpindi district of the Punjab, petroleum is found at sixteen localities. The most productive spring appears to be at Gunda, where for six months an average of 11 gallons a day was obtained from a boring 75 feet deep.

There can be no doubt that the oil resources of the coal-fields of Upper Assam are very great. Borings for petroleum at Makum gave highly satisfactory results. None of the boreholes were deeper than 200 feet, yet in some the oil spouted intermittently with a pressure of 30 lbs. to the square inch, the yield being as

much as 3,500 gallons in thirty-five hours from a single pipe. Owing to the difficulties of transport the enterprise was abandoned. At the present time, the best ground is within the concession granted to the Assam Railways and Trading Company; but the oil is neglected.

The coast of Arakan and the adjacent islands have long been remarkable for the mud volcanoes caused by the eruption of hydrocarbon gases. Petroleum occurs in the neighbourhood, as much as 40,000 gallons a year being exported by the natives from Kyoukpyu. The oil is very light and pure. In 1877 European enterprise was attracted to this industry, and excellent results were at once obtained. In 1879 works were undertaken by the Borongo Oil Company. The company started work on a large scale, and in 1883 had twenty-four wells in operation, ranging from 500 to 1,200 feet in depth, one well yielding for a few weeks 1,000 gallons daily. The total amount of crude oil pumped from ten wells during the whole year was not more than 234,000 gallons; and in 1884 the company had to suspend payment. Large supplies of high-class petroleum could, without doubt, be obtained from this region if suitable methods of working were employed.

Rangoon oil, probably an object of industry in prehistoric times, comes from Upper Burma, from Yenanchaung on the east side of the Irawadi. The greater portion of the yield is sent to Rangoon. The quantity sent during the year 1883–84 amounted to 1,000,000 gallons. The oil-resources of Burma undoubtedly admit of an indefinite extension of enterprise, yet the country still imports 2,000,000 gallons of American mineral oil annually.

The oil-measures of the Khátan field, in the Mari hills of Baluchistan, are described by Mr. R. A. Townsend. Petroleum is found exuding close to some springs of sulphurous water; and along the edge of the marine conglomerate (limestone breccia) there are beds of petroleum mixed with gravel and earth, often 15 feet in thickness. In sinking bore-holes, great difficulty was experienced in keeping the hole straight in the highly disturbed and broken conglomerate, the drill having a tendency to follow the direction of the crevices. The petroleum of this locality, it is suggested, may be produced by the action of sulphurous acid waters combined with alkalies upon a deep-seated deposit of coal or lignite, and it may be possible that all petroleum has a similar origin. This theory is supported by the fact that all producing oil-fields are in strata containing sulphur, salts, and alkalies. The theory is, however, not accepted by Mr. H. B. Medlicott. The association of the petroleum with the salts and sulphurous products is, in his opinion, only incidental, or, at most, concomitant. It is very possible that there is deep-seated coal beneath all this ground; but there is no necessity for the assumption, seeing that the description given is the most satisfying yet on record, that the oil is indigenous in the Eocene rocks.

B. H. B.

Use of Petroleum as Fuel in Locomotives.

By E. W. M. Hughes.

(Professional Papers on Indian Engineering, vol. iv., 1886, p. 97.)

The Author has made a series of careful trials to determine the economy of petroleum as fuel, in comparison with coal, patent fuel, and wood. The oil, with which the experiments were made, was that collected by Mr. R. A. Townsend in his experimental borings in the Khátan field, Baluchistan.[1] Two locomotives were fitted for burning petroleum, and commenced running on the 20th of June, 1886, between Sukkur and Radhan, on the Indus Valley State Railway. Unfortunately, it was not convenient to run engines of the same type over the same piece of road with other descriptions of fuel, so that an exact comparison of the consumption cannot be made. A similar series of experiments made with great care on the line between Radhan and Kotri may, however, be taken for the purpose of comparison. The cost per 100 miles worked was found to be 54·23 rupees with patent fuel, 51·14 to 57·4 rupees with coal, 15·8 to 30 rupees with wood, and 36·8 rupees with petroleum. The average evaporative power of petroleum is 9·82 lbs. of water per lb. of fuel; the corresponding figures for patent fuel and coal being 7·71 and 6·91 respectively. The consumption of oil per train-mile was 27·42 lbs. More economical results may yet be obtained with petroleum, since the trials were made by drivers unacquainted with its use; whilst the trials with coal, patent fuel, and wood, were made by men who had been using these fuels for years. From the results of his trials, the Author is satisfied that no other fuel in India can compare with petroleum for locomotive-purposes.

Petroleum has also been used in a stationary boiler, with spray-injectors similar to those used on the locomotives. The Khátan petroleum being so much heavier and thicker than the Russian or American oils, a new type of injector had to be designed. The one adopted is modified from the Russian type. Experiments have also been made with petroleum in a tire-furnace, air from the smithy blast-pipe being used for diffusing the spray. A great saving of fuel is effected in this case. The jets being turned off as soon as the tires are sufficiently heated, the fuel that would otherwise be left in the furnace is saved.

B. H. B.

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[1] *Ante*, p. 525.

On Improvements in Steam-Pumps and in their Mode of Working.

By Professor F. Reuleaux.

(Protokoll des Verein für Eisenbahnkunde, 9 November 1886.)

The Paper commences by showing that in a direct-acting steam-pump the steam-pressure must be almost constant through the entire stroke, so that it may overcome the water-pressure, which is uniform; this leads to an efficient water-end but an extravagant steam-end. This can be partly remedied by attaching a heavy mass to the pump-rod, so that by its inertia the steam may be cut off earlier in the stroke, while at the same time the water-pressure remains constant, and by this means direct-acting pumps have been worked with a cut-off at two-fifths of the steam stroke.

The simplest and most usual way of making the steam-end economical is by storing up the excess and deficiency of power by means of a fly-wheel, and in that case a rotative engine is produced but the water-end suffers, and owing to the varying delivery of water throughout the stroke, the flow varies in both quantity and pressure. Pump-valves are also more difficult to make for rotative engines. Two pumps and engines are frequently coupled at right-angles, and in that case the flow is more uniform and the air-vessel volume can be reduced. In America the Gaskill Company has reduced the space occupied by a rotative engine by returning the connecting-rod, and placing the crank-shaft over the pump-case, and an engine on this system, which was tested by Mr. Porter, gave very economical results. In Europe this is not done, as accessibility of parts is considered of more importance than space. Stretching out an engine causes the foundations to be more expensive, and this point should always be taken into account in the first cost of the machine. Direct-acting engines, without fly-wheels, have received more attention in America than in Europe, and descriptions are given of Messrs. Merryweather's and Shand and Mason's engines, and also Cameron's pump, made by Messrs. Tangye; but for deep-mine pumping the use of hydraulic spears is preferable to taking steam down a shaft, and good examples of this are found at Sultzbach Altenwald, in Saarbrücken, and also in those made by the Cologne Company.

The direct-acting engines of Blake, Knowles, and Deane are described. The auxiliary valves of the latter are compared to the escapement action of a watch; and by working out this theory, a twin engine is arrived at, that is, two engines and pumps coupled together, one engine working the other's valves. This arrangement was brought out by Messrs. Worthington, of New York, and has been most successful. At the Philadelphia Exhibition of 1876, a large engine on this system received great attention. By this twin-action an almost perfect delivery of water is obtained. The following performances of these engines are of special interest:—

Pumping Station.	Description of Engine.	Cost of raising 1 million gallons 1 foot.				
		1872.	1873.	1874.	1875.	1876.
		Cents.	Cents.	Cents.	Cents.	Cents.
Belmont .	Two Worthington pumps .	7·00	7·68	7·08	7·84	7·07
Roxborough	One Cornish engine, one Worthington pump . .	9·90	9·92	9·19	10·30	9·51
Delaware .	One high-pressure, one low-pressure engine, one Worthington pump	13·20	13·14	14·35	12·98	12·69
Schuylkil .	Two Cornish engines, one double-cylinder rotary-geared engine, one cross-framed engine rotary-geared	11·20	17·36	16·97	17·05	13·40
Germantown	One high-pressure rotary-geared engine	36·20	..	..	..	..

These twin-engines have therefore found great favour, and the adoption of the compound system materially assisted their economical working.

The new patented system of using compensators is then described in almost a similar manner to that given in the Paper, "Mair on a Direct-Acting Pump,"[1] and the trials there given are alluded to. The action of the compensators is described as very perfect, and the saving in steam by their use is given at 40 to 60 per cent.

The Author concludes by stating that this new form of engine has marked a new era of progress in the application of steam power.

J. G. M.

Results of Tests with Malleable Cast-Iron. By A. Martens.

(Mittheilungen aus den Kœniglichen technischen Versuchsanstallen zu Berlin, 1886, p. 131.)

The experimental Institute was commissioned by the firm of Messrs. Michaelis and Casparius, of Berlin, steel and malleable cast-iron founders, to determine the strength of their materials, and subject a portion of their manufactured articles to thorough tests, varying in their character according to the nature of the article.

The tensile tests were made with rough annealed castings of about 40 by 6 millimetres (1·58 by 0·24 inch) section, and a length between the shoulders of 300 millimetres (11·81 inches) in the Werder testing-machine. For recording the extensions Bauschinger's mirror-apparatus was used. One series of tests was carried out with pieces in their ordinary condition, while a second was made with welded test-pieces of as nearly as possible the

[1] Minutes of Proceedings Inst. C.E. vol. lxxxvi. p. 293.

same dimensions as those used in the first series. The parts to be welded were heated in a fire of wood-charcoal and well-coked forge-coal, and the operation was finished in a single heat.

The results are given in a tabular form in the original; the averages of the first series of tests were as follows:—ultimate tensile stress, 25·8 kilograms per square millimetre (16·38 tons per square inch); contraction, 8·2 per cent.; extension in a length of 200 millimetres (7·87 inches), 2·5 per cent.; limit of elasticity, about 7 kilograms per square millimetre (4·44 tons per square inch). For the second series of experiments with welded test-pieces the average results were: ultimate tensile stress, 30·3 kilograms per square millimetre (19·24 tons per square inch); contraction, 13·3 per cent.; extension in a length of 200 millimetres (7·87 inches), 1·1 per cent.; in each case the fracture took place outside the welded portion.

The experiments with manufactured articles were made on a considerable variety of objects, including scissors, rifle-fittings, stirrups, &c., which, according to their character, were subjected to bending hot and cold, twisting, and blows from a hammer; test-pieces of the form used in the previous experiments were also tested in a similar manner, and in some cases exposed to very severe treatment. In one instance a test-bar was made red-hot and bent double, welded together for a certain distance from the bend, and the welded portion flattened out to nearly three times its original width under the steam-hammer; the two free ends were then bent double round a radius of 35 millimetres (1·38 inch). For each operation the piece was re-heated.

The welding with the material tested appeared to be very satisfactory.

The original is illustrated by numerous woodcuts in the text, and a fac-simile of a photograph taken from the pieces after the experiments. G. R. B.

Tests of Chrome and Mild-Steel Plates by various Makers.

(Mémorial de l'Artillerie de la Marine, 1886, pp. 1–16.)

The plates under consideration are those that would be used as shields for protection against the fire of rifle-bullets and machine-guns.

In 1884 experiments were carried out by the Gâvre Committee with chrome and mild-steel plates, which resulted in establishing the superiority of chrome steel for plates of 0·10 inch thickness, but plates of 0·6 to 1·18 in. thickness were considered too brittle to compensate for their slight extra resistance to perforation. The latter having been replaced by the manufacturers with harder plates, the trials were continued under the same conditions with some special steel plates of St. Chamond make.

The 1884 results were taken as standards of comparison, and the firing took place with hard lead balls from rifles, and with

37- and 25-millimetre machine guns, to determine the velocity absolutely necessary to penetrate at 80° angle direct fire, a 30° angle was also tried with 47, 37 and 25 millimetre guns; after each round, the perforation, effects of explosion, state of projectile and plate were carefully noted.

The plates were each 6 feet 6¾ inches by 3 feet 3⅜ inches square, and three plates of each thickness, viz., 0·10 inch, 0·6 inch, and 1·18 inch thick were used.

The construction of the targets is illustrated and described, and the plates are classified in order of merit after the various rounds. The plates were all tested for tensile strength after firing, the result showing that those which best resisted the firing were not necessarily the highest in tensile strength; for example, a plate with a high tensile strength was inferior to a plate with 30 per cent. less strength—or even one with 60 per cent. less strength.

As it was found impossible to establish any relation between the resistance to firing and the tensile strength, it was clearly shown that it would not be safe to accept plates on the latter test, so the Committee drew up new conditions of reception including a firing test. These are given in detail, also the effects of the various rounds fired. The conclusion was, that generally speaking the plates were too brittle, except in one instance.

Experiments will be continued in the works of the manufacturers to arrive at the production of plates equal to the one referred to. J. H. R. W.

On the Phenomena which occur during the Heating and Cooling of Cast Steel. By — OSMOND.

(Comptes rendus de l'Académie des Sciences, vol. ciii. 1886, p. 743.)

The Author sought to discover whether the phenomenon of recalescence to which Mr. Barrett first drew attention, as taking place in hard iron, was due to heat spontaneously set free in cooling it from a white to a red heat, or required the presence of carbon. He experimented upon cast-steel of different degrees of hardness between the ordinary temperature and 800° Centigrade (1,472° Fahrenheit), and concludes that there are two distinct phenomena, one of them due to a molecular transformation of the iron, and the other to a change in the relations between the iron and the carbon.

E. F. B.

Comparison between the Different Systems for the Transmission of Power. By JULES LAURIOL.

(La Génie Civil, vol. ix. 1886, pp. 313 and 343.)

The principal means employed for transmitting power to a distance are: electricity, water-pressure, compressed air, and ropes.[1]

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[1] Minutes of Proceedings Inst. C.E. vol. xlix. p. 1; and vol. xliii. pp. 53 and 105.

The cost price of a unit of work, in any given place, depends upon the cost of the power supplied, the efficiency of the transmission, and the cost of the establishment and maintenance of the means of transmission. The cost of the power varies greatly, according to the method of its production, the size of the machine, the number of hours of work, and the price of wages; it is least with a water-wheel or turbine, and greatest with a gas-engine or a small steam-engine. The efficiency of electric transmission is the product of the three partial efficiencies of the generator, the conducting line, and the receiver; and from calculations of these several efficiencies, and allowing 16 per cent. for interest and repayment of capital, the price is deduced of each effective HP. per hour after the transmission of a given power a given distance. Assuming that the power is generated by a large steam-engine, burning 2¾ lbs. of coal per HP. per hour, and working twenty hours per day, the cost per effective HP. per hour transmitted is 2·1*d.*, 2·8*d.*, and 5·5*d.* for 5 HP. transmitted distances of 330, 16,400, and 65,600 feet respectively, and 1·6*d.*, 1·95*d.*, and 4*d.* for 50 HP. transmitted similar distances. If it is generated by a hydraulic machine, the cost is 0·7*d.*, 0·93*d.*, and 2·05*d.* for 5 HP.; and 0·42*d.*, 0·55*d.*, and 1·13*d.* for 50 HP. transmitted the same distances respectively. Transmission of power by water under pressure is chiefly used at seaports and docks for working dock-gates, swing-bridges, capstans and cranes. The power thus supplied is readily estimated by measuring the volume of water passed, an advantage not possessed by other systems. The establishment, however, of conduits for the transmission of water-pressure, and also of compressed air, is far more troublesome and costly than for the transmission of electricity; and though a general distribution of water under pressure would enable a fire to be quickly controlled, it would expose the buildings to injuries from leakage. Moreover, water-pressure might become inoperative during severe frosts; and its machinery could not be so readily removed to another site, as in the case of electrical transmission. From a Table giving the cost of 5, 10, 50 and 100 effective HP. per hour, transmitted various distances by water-pressure, compared with a similar Table for electrical transmission, it appears that the cost of transmission by water-pressure is always the greatest, becoming five times as much for 5 HP. transmitted long distances, though only from two to three times as great with 100 HP. for the same distances. The low efficiency of transmission by compressed air renders its application only advantageous where efficiency is a secondary consideration, as in the boring of tunnels and piercing the headings of mines, where the air supplies the necessary ventilation. The actual efficiency of this system of transmission is 45 per cent. up to distances of about 1,650 feet, diminishing to 35 per cent. for distances of 65,600 feet. The Table giving the cost of the effective power transmitted by compressed air shows that this system is dearer than water-pressure for short distances, is about the same for a distance of 16,400 feet, and becomes cheaper for longer

distances. The transmission of power by wire-ropes working round pulleys has been successfully employed at Schaffhausen, Bellegarde, Fribourg and Zurich, the ropes being supported on rollers at intervals of about 330 feet. The large cost of maintenance is prejudicial to this system; and the primary extension of the ropes, their subsequent variations in length with changes of temperature, the dangers attendant on their rupture in frequented places, the difficulty of making any extensive subdivisions of the force, and the impossibility of measuring the amount of power transmitted, render the system inconvenient. Its efficiency, however, is very great for distances not exceeding 3,300 feet, being 96 per cent. for 330 feet, 93 per cent. for 1,650 feet, and 90 per cent. for 3,300; but it is reduced to 60 per cent. at 16,400 feet, 36 per cent. at 32,800 feet, and to only 13 per cent. at 65,600 feet. Accordingly, whereas the cost of transmission of power by ropes, as shown by the corresponding Table, is much less than even by electricity up to 1,650 feet, this advantage disappears at 3,300 feet; and for a distance of 65,600 the cost with ropes is greater than with any of the other systems. The transmission of power by supplying gas to a gas-engine at a distance is extending, in spite of the high price of the power obtained, owing to the facility with which these engines are set up and set going. The transmission of power by steam was tried at New York, but it was abandoned, as the steam condensed in the underground pipes, and the water was ejected. The exhaustion of air for the transmission of power has been employed recently in Paris, but its efficiency is but little higher than that of compressed air, without reckoning the inconveniences which might attend its working. It is evident from the Tables of cost of the four principal systems of transmission that, except under special local conditions, the system of ropes is cheapest up to distances of about 3,300 feet, and that electrical transmission is the cheapest for longer distances, and far superior to water-pressure and compressed air. The following Table indicates the cost of transmission of 100 HP. to given distances, by the four systems:—

System employed.	330 Feet.	1,640 Feet.	3,280 Feet.	16,400 Feet.	32,810 Feet.	65,620 Feet.	Motor.
	d.	d.	d.	d.	d.	d.	
Electricity .	1·80	1·84	1·94	2·27	2·84	4·61	Steam.
Water-pressure	2·27	2·36	2·61	4·03	5·79	9·57	Steam.
Compressed air	3·17	3·23	3·33	4·05	5·25	6·39	Steam.
Ropes . . .	1·26	1·49	1·58	2·88	4·99	12·68	Steam.
Electricity .	0·46	0·48	0·53	0·62	0·68	1·15	Hydraulic.
Water-pressure	0·46	0·55	0·62	1·33	2·23	3·54	Hydraulic.
Compressed air	0·72	0·80	0·84	1·21	1·86	3·36	Hydraulic.
Ropes . . .	0·25	0·27	0·30	0·80	1·42	3·39	Hydraulic.

L. V. H.

Experiments on the Transmission of Energy by means of Dynamo-Electric Machines Coupled in Series. By HIPPOLYTE FONTAINE.

(Comptes rendus de l'Académie des Sciences, vol. ciii. 1886, p. 727.)

This is a report of experiments made with Gramme machines. The generator comprises four machines, coupled in tension and actuated directly by two large pulleys, keyed to the same shaft. The machines are placed on either side of the pulleys, so as to equalize the lateral pressures on the bearings. The motor consists of three machines in series. The machines employed were of the ordinary Gramme type.

Preliminary experiments proved the necessity of not exceeding an intensity of current of 11 amperes, if it was desired to work for twenty-four hours without abnormal heating; and that 1,600 volts was the maximum practical electro-motive force that could be employed economically. This corresponded to a velocity of about 1,400 revolutions a minute. Having started the seven machines, and placed between the two groups a resistance of 100 ohms, it was proved that 50 HP. could be transmitted under practical conditions.

Diagrams were taken on the cylinder of the steam-engine working the generating-machines and a Prony brake alternately, by which means the energy exerted in each experiment was measured with sufficient accuracy. The following Table gives one set of results :—

Velocity of the steam-engine	56 revolutions.
„ generating-machines	1,298 revolutions per minute.
Difference of potential at the extremities of the first machine	1,490 volts.
„ „ „ second „	1,505 „
„ „ „ third „	1,493 „
„ „ „ fourth „	1,508 „
„ „ origin of the conducting-wire	5,896 „
Intensity of the current	9·34 amperes.
Resistance of the line	100 ohms.
Work on the piston of the engine	112·8 HP.
Efficiency of the steam-engine	85 per cent.
Work received by the generating-machine and the mechanical transmission	95·88 HP.
Velocity of the motor-machines	1,120 revolutions.
Work on the brake	49·98 HP.
Efficiency	52 per cent.

The weight of the seven machines was 8,400 kilograms (19,480 lbs.), or 167 kilograms (3,674 lbs.) per HP., transmitted through a resistance of 100 ohms.

E. F. B.

Elastic Coupling for Shafting. By — Pihet.

(Bulletin de la Société d'Encouragement, November 1886, p. 548.)

Mr. Raffard has invented an elastic coupling specially suited to high-speed shafting, in which want of exact alignment of the shafting, from whatever cause arising, is perfectly compensated by the elastic connections employed. On each of the adjoining ends of the two lengths of shafting a disk is keyed, and the disks are linked together by endless bands of india-rubber, which are looped over studs on the inner faces of the disks, in the manner of drag-links. That the links may act free of each other, the studs of one disk are set in a circle of a diameter different to that in which the studs of the other disks are set. The shafts are carried in separate bearings, one behind each disk. There are two, three, four, or more links, according to the power transmitted.

In the special case which engaged the attention of Mr. Raffard, —the coupling of electro-motors—he has obtained remarkably good results from the employment of india-rubber for the drag-links, a material which, though liable to be decomposed by oil, is, for its superior qualities—amongst others that of an insulator—better suited for such special purposes than other materials. In other applications, metal connections are available.

For more than a year Mr. Bréguet has employed the elastic coupling in his workshops, and for six months in other ways, especially on board the steamship "Champagne," of the Trans-atlantic Company, where 35 HP. is transmitted from two steam-engines driving three Bréguet dynamo-machines, at a speed of 300 revolutions per minute. The disks are 28 inches in diameter, and carry twelve studs on each; placed in a circle of 20 inches and 24 inches respectively. These are connected by links of india-rubber, the section of which is 1·38 inch by 0·40 inch. The studs of one disk carry brass sleeves, over which the links are passed, and which help to reduce the frictional action on the links arising from the continuous slight adjustment which takes place when the shafting is not in exact alignment. The links are subject to a stress of about 40 lbs. per square inch of their original section, with an elongation of 43 per cent. The breaking-strength is four times the working-stress, with an extension of 300 per cent.

D. K. C.

Seger's Pyroscope, and Observations on the Working-Temperature in the Interior of Gas-Retorts. By Dr. A. Heintz, of Saarau.

(Journal für Gasbeleuchtung, 1886, p. 894.)

Retort- and other furnaces are now worked at much higher temperatures than they formerly were, and it is desirable to have the means of measuring the heat developed in various parts of the furnaces. Temperatures are easily measured so long as alcohol

and quicksilver thermometers can be used, but the former are useless at a very moderate temperature, and the latter become untrustworthy when the temperature approaches 300° C., and quite useless at 360° C. Numerous ingenious attempts have been made to find a practical means of measuring high temperatures, either by the expansion of air or of solid bodies, but none of them, not even Siemens's electric pyrometer, have entirely succeeded; the latter is impracticable on account of its expensiveness, and, if frequently very highly heated, the resistance of the platinum wire is altered. More reliable results are to be obtained by observing the transition of materials from the solid to the fluid state; these range between −39° C. for quicksilver to 1,075° C. for gold. Becquerel has given the melting-point of platinum between 1,460° and 1,580° C.; Deville, on the contrary, gives it at 2,000° C., and Violle at 1,779° C. These variations arise not only from the difficulty of measuring such high temperatures, but also because the melting-point of platinum is easily influenced by exceedingly small quantities of iridium, a metal frequently found with it; while, if exposed to a white heat in the presence of flinty matter, it becomes much more easily fusible. For higher temperatures it is desirable to have materials with gradually increasing melting-points, and which are not influenced by the oxidizing or reducing nature of the flames. Professor Seger, of the Royal Porcelain Works, Berlin, has lately introduced pyroscopes, which are easily applied, and their cheapness admits of their being largely used. For temperatures between the melting-points of silver and gold, alloys of these metals may be advantageously used, each increase of 20 per cent. of gold corresponding to an increase of about 23° C. in the melting-point; above 1,075° C., the melting-point of pure gold, alloys of gold and platinum may be employed, but Professor Seger finds that with more than 20 per cent. of platinum the alloys are irregular with regard to their melting-points. Professor Seger's pyroscopes for temperatures from 1,200° C. upwards are composed of quartz, kaolin, white marble, and felspar, the raw materials used for the glazing of Berlin porcelain, and, according to his experience, the glazes, poor in clay and containing much alkali, have the highest points of fusion. For the preparation of the tests the glazing is thoroughly mixed, and formed with gum-water into tapering blocks having triangular bases, the blocks being about $2\frac{1}{4}$ inches high, and the sides $\frac{6}{10}$ inch wide at bottom; they are fixed upon fire-clay slabs or boxes, and are easily introduced into and withdrawn from a furnace in action; they have numbers from one to twenty stamped on them, each number having a known melting-point; when the block commences to fuse and run down it is assumed to have reached its melting-point. The No. 1 pyroscope fuses at about the melting-point of a mixture of 90 per cent. gold and 10 per cent. platinum, or about 1,150° C.; while the No. 20 fuses at the highest temperature of the large gas-ovens at the Berlin Porcelain Manufactory, or at about 1,700° C.

For observing the internal temperatures of gas-retorts at

different stages of the process of distillation, fire-clay boxes of about 4 inches diameter may be used, with fitted covers and with holes in the sides to keep the internal temperature the same as that by which they are surrounded, and if divided into compartments they may be filled with pyroscopes of different melting-points. If it is desired to determine the temperature in the middle of a retort, it is charged up to that point, and the pyroscope is inserted; the charge being then completed, the front part of the charge can be withdrawn at the required time, and the pyroscope taken out and its contents examined. By this means it was found that, with the furnace at full heat, the temperature in the middle of a retort, after one hour, was 460° C.; after three hours, 960° C.; and after five and a half hours, 1,075° C. Simultaneous observations taken in the furnace at the middle of the retorts, and 4 feet 6 inches above the fire-bars, gave a temperature of 1,400° C., when Seger's No. 10 pyroscope was completely melted, and the No. 11 commenced to fuse.

C. G.

Gas-Furnace with nine Inclined Retorts, Producer, and Recuperator, at the Rheims Gasworks.

(Portefeuille économique des Machines, 1886, col. 161.)

The troublesome part of gas-making lies in the charging and discharging of the retorts. To meet the tendency of wages to rise, to obtain quicker and better work, and independence of strikes, special machinery or retorts of improved form are wanted in place of the shovel or spoon for charging, and of the hook for discharging. The use of steam, or of compressed air or water, for distributing the charge gives economically doubtful results.

Mr. Coze has established at Rheims a battery of four nine-retort furnaces, detailed drawings of which accompany the Paper. The main idea is the inclined position of the retorts, whereby the charge of coal penetrates into, and passes out from them by gravitation, reducing manual labour to a minimum. Each quarter of the construction comprises a producer, a recuperator, and nine retorts. Dust of coal and of coke being difficult to sell, Mr. Lencauchez was asked to study a producer to use them. He gives 1,000 kilograms of fuel per square metre of section (205 lbs. per square foot) per twenty-four hours as the charge of a producer supplied with coke. The dimensions at Rheims allow of a charge of 2,000 kilograms (nearly 2 tons) of coke, and as 50 per cent. of fuel of inferior quality is used, the section is exaggerated.

Each producer is isolated, and is 4·1 metres (13·45 feet) long, by 2·9 metres (9½ feet) broad, outside measurements. The inside space has the form of a straight rectangular prism cut below by an inclined plane, on which a grating lies. Coke is introduced at the

top of the producer on the ground line. A curtain-wall compels the gases to traverse all the incandescent mass on their way to the conduit, and so ensures complete decomposition of CO_2. A small supply of water constantly trickles down on the grating, which partly turns to vapour and is decomposed into useful gases by the incandescent coke, and partly keeps the hearth moist enough to prevent formation of clinkers. Scoria can be removed by the spade. Two large wrought-iron doors before the grating prevent radiation and entrance of air, the supply of which is regulated by a damper at the side of the doors. Two rows of bricks, placed on edge and bedded in mortar of Portland cement and fine sand, form a water-tight hearth. In order to allow the sides of the producer to expand, and to prevent escape of gas through the interstices of the masonry, a space inside the walls 0·11 metre (4½ inches) broad is filled with sand. A channel similarly sealed receives the gas beyond the curtain-wall and conveys it to the burners.

Each recuperator lies beneath the corresponding furnace. All parts subjected to heat are exposed on one side to the flames, on the other to the air to be heated. It is air-tight and causes a thorough circulation of the air along the heating-surface, which amounts to 8·9 square metres (10·64 square yards) per retort. The producers face the recuperators and are separated from them by a service lobby, from which the introduction of air and the passage of smoke to the chimney are controlled.

A gallery 2½ metres (8·2 feet) long, of 635 litres (22·4 cubic feet) capacity, spacious enough to slacken the speed of, mix, and distribute the gases regularly to the burners, lies between these and the producer. It is surrounded by an annular space containing heated air from the recuperator. The burners, rising from the gallery of the gases, cross the hot-air space, and gas and air mix as in a Bunsen burner. Five rows of three burners occupy the length of each furnace and equally distribute the heat. The outlets amount in all to 0·0906 square metre (0·975 square foot) for gas, and to 0·1184 metre (1·274 foot) for hot air.

The roof, in refractory bricks enveloping the retorts, has an inclination of 30°, is of elliptic-like section and 3·85 metres (12·63 feet) broad, by 1·4 metre (4·6 feet) high.

The roof of the burners is arched over to carry the walls supporting the middle retorts, a clearance of 3 centimetres (1·18 inch) being left so that it may expand, or be repaired, without interfering with the construction of the furnace.

For the junction of the charging-tubes to the retorts, the latter are prolonged 1 inch beyond the furnace-wall, and boxed into the iron elbow-shaped terminals of the former. So the joints are air-tight and protected from the heat of the furnace by a 0·4-metre (15¾ inches) wall. The formation of the retorts in one piece conduces to regularity of charge.

The charge is brought up in small wagons, running on rails on the roof, and so made that whatever be the inclination of the boxes on them, from which the material is dropped, it falls verti-

cally on the same spot. Hinged covering-lids prevent loss of coal in loading and regulate its introduction. For discharging the retorts the lower door is opened, and a flat iron inserted to raise slightly the layer of coke, which slides out into a hopper.

A. B.

Gas-Calciner for Zinc Ores. By E. Ferraris.

(Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 1886, p. 655.)

In order to calcine the calamine from the dressing-floors of the Monteponi mine, in Sardinia, the Author has constructed a reverberatory furnace, which has been in operation since the 1st of January, 1886, with very satisfactory results. The furnace consists of a hearth 12 yards long, inclined at an angle of 45°. At the top is a cast-iron hopper through which the calamine to be calcined is charged, and at the bottom is an aperture for removing the calcined ore. The furnace is a double one, the gas-producer and stack being common to both hearths. There are five working doors on each side of the furnace, and, as the hearth is double, all the working doors on one side may be opened without interfering with the production of gas. The gas-producer is of the Boëtius type. The cost of erecting a double furnace of this kind is £800, £200 of which are for excavations and roofing, whilst the furnace itself costs £600.

The results obtained during March and April, 1886, were as follow:—In March 642,270 tons of calcined ore were produced, the consumption of fuel (lignite) being 64,550 tons. In April 580,380 tons of ore were produced, the consumption of fuel being 56,980 tons. The calamine contains a large quantity of blende, sometimes as much as 50 per cent. of the mass. The sulphur is, however, completely eliminated. The size of the ore has hardly any influence on the results; fragments of calamine the size of a fist being calcined as perfectly as the fine slimes from the dressing-floor. The cost of calcination, calculated per ton of calcined calamine, is as follows:—Labour, 1*s.* 10*d.*; fuel, 1*s.*; total, 2*s.* 10*d.*

B. H. B.

On Wire-Ropes of Diminishing Section for Deep Shafts, and on Winding-Drums for the same. By E. A. Brauer.

(Zeitschrift des Vereines deutscher Ingenieure, 1886, p. 1102.)

This Paper contains an exhaustive series of formulas for the determination of the strains and dimensions of wire-ropes of varying diameter, and for the construction of winding-drums with graduated spiral grooves to correspond to any length of such rope. In very deep shafts the dead-weight of the rope itself is the chief

item in the working-load; and to secure equal strains in every part, and to lessen the weight, it is advisable to make the rope of diminishing section. The exigencies of practical manufacture render it inadvisable to vary the diameters of the several wires, so that the usual method is to lessen the number of wires stage by stage. To secure uniform increment of section, the following numbers of wires are preferable (the figures in brackets referring to the number of wires in concentric rings):—5, 6, 7 (1–6), 8, 12 (3–9), 14 (4–10), 16 (5–11), 18 (6–12), 19 (1–6–12), 20 (7–13), 22 (8–14), 27 (3–9–15), 30 (4–10–16), 33 (5–11–17). Hemp core is required with 5, 6, 7, 8, 18, 20 or 22 wires. The lengths now commercially available are—

Diameter. Inch.		Length in Yards.
0·109	(between 11 and 12 B.W.G.)	766
0·098	„ 12 „ 13 „	930
0·087	„ 13 „ 14 „	1,203
B.W.G.		
No. 14		1,476
„ 15		1,859
„ 16		2,297
„ 17		3,063
„ 18		4,156
„ 19		6,015

P. W. B.

On Iron Framing for Pit-roads, at the Rochebelle Collieries.

By — GERRARD, Engineer to the Collieries.

(Bulletin de la Société de l'Industrie Minérale, vol. xv. 1886, p. 391.)

After describing the necessity for driving and maintaining long roads for haulage and other purposes at the Rochebelle collieries, under unusual difficulties from faults, shifting ground, &c., and the failure of timbering of the stoutest dimensions, even when carefully framed and mortised together, the Author proceeds to give examples of various forms of iron-arched frames, with straight vertical sides, resting on wooden cross-sleepers, and of horse-shoe and elliptical iron frames, all of which failed. Finally, circular frames made in halves, and united either by fish-plates or by sockets or chairs keyed up with wooden wedges, were adopted, and with complete success. These were variously made of T or channel-iron, weighing from 7 to 11 lbs. per foot, and of old rails of Vignoles and other sections, weighing from 10 to 16 lbs. per foot, and in three standard sizes, viz., 5 feet 11 inches, 5 feet 3 inches, and 3 feet 11 inches interior diameter, for main, secondary, and branch roads respectively.

The frames are bent hot on a wheel of suitable diameter revolving against a friction-roller, and the ends are then squared up so as to butt truly against each other. The average cost for light frames

may be taken as follows, but a correction must be made if heavier rails are required to be used:—

	s.	d.
20 feet of old rails at 10 lbs. per foot, say 200 lbs. at 4s. per cwt.	7	2
2 sockets, wrought iron, at 4d.	0	8
Bending	0	9½
Trimming	0	9½
Fuel	0	6
Cost per frame	9	11
Packing, 100 feet round poles	1	11
Fixing	0	10
	12	8

As these frames are fixed about 1 yard apart; this at once gives the price per lineal yard. In the main road, where these were first tried in competition with timber frames, not a frame has been forced out of shape, and the packing is still good.

Wooden frames in the same road have cost, including repairs, 16s. 9d. per lineal yard during the same period, and a further sum of 2s. 7d. per annum must be allowed for future repairs; the result is, therefore, decidedly in favour of the iron frames.

In other parts of the pit, and under varying conditions, the results have been found equally in favour of the iron frames, which are now being substituted for the wooden frames or timbering wherever replacement becomes necessary.

An important advantage of this system is the small space that it takes up, and the consequent saving in excavation. For example, if iron frames 5 feet 11 inches in diameter are compared with timbering and brick arching, the following results are obtained:—

—	Cross-section of Roadway.		Proportion.
	Gross.	Clear.	
	Square feet.	Square feet.	Per cent.
Iron framed	33·8	27·4	81
Timbered	78·6	40·9	52
Arched	84·5	31·2	37

In other words, every square foot of useful cross-area of roadway, if lined with iron frames, requires 1·23 square foot of excavation; with wood frames, 1·92 square foot; and with masonry arching, 2·70 square feet.

Taking this element into consideration, the price per lineal yard for excavation and lining will be:—

	£	s.	d.	
Iron framed	2	3	0	per lineal yard.
Timbered	2	10	8	"
Arched	3	8	0	"

Additional advantages.—The area of the air-way remains constant, instead of being diminished by the steady crushing-in of the timbers; the air is not vitiated to the same extent by the rotting and fermentation of the timbers; the haulage is not hindered by frequent repairs and replacements (out of more than 2,000 iron frames now in use not more than 2 per cent. have been broken); the floor does not "creep," and the rails maintain their level.

Iron packing and sheeting.—The principle of metallic lining has been still further extended by the adoption of iron instead of wood for packing and sheeting; for this purpose iron laths $2\frac{1}{4}$ inches by $\frac{1}{4}$ inch, $1\frac{3}{4}$ inch by $\frac{1}{16}$ inch, $\frac{3}{4}$ inch by $\frac{1}{8}$ inch, $\frac{5}{16}$-inch square rods, and wire $\frac{1}{4}$ inch in diameter, have been tried; and although no definite results or comparative figures have yet been worked out, there seems little doubt of the ultimate success of this system, if judiciously applied.

It is a mistake to pack the linings, of whatever material composed, too tightly at first, as it is found better to let the pressure come on gradually and distribute itself equally.

The Paper, which goes into considerable detail, is illustrated by numerous sketches, and by two sheets of engravings, giving full details of the nature of the ground passed through, and the faults and other difficulties encountered, and of the various framings and packings employed.

W. S. H.

On Self-Acting Stops for Inclined Planes.

By E. Larmoyeux and A. Demeure, Mons.

(Annuaire de l'Association des Ingénieurs sortis de l'École de Liége, 1886, p. 365.)

According to a computation by Mr. E. Harzé, Chief Engineer to the Corps des Mines, some 12 per cent. of colliery accidents in Belgium occur on self-acting jig-roads, or inclined planes, where the weight of the loaded tubs descending raises the train of empties. A runaway train from the top probably means injury or death to the hanger-on at the bottom. A thoroughly trustworthy stop, or block, is therefore a matter of great importance.

Passing by Mr. Savoie's plan, as being only applicable to single trams, and not to a train of tubs, and that of Mr. Dessent (consisting of a catch reaching only from $1\frac{1}{4}$ to $1\frac{1}{2}$ inch below the top of the tub) as liable to failure when the tubs are old or battered, Mr. Larmoyeux proceeds to describe Mr. Tellier's system, consisting of a wooden bar 4 inches in diameter slung from the strand of an old winding-rope fixed across one of the wooden frames supporting the roof, and hanging at such a height as to prevent the passage of a tub, unless it is raised by a hand-line passing over a pulley. Loops of the same strand are so attached as to prevent undue side-oscillation. When in place, the ends of the bar rest firmly against

the timbering, but so as to be free to swing out of the way of an ascending wagon. To prevent the necessity of holding up the bar by hand during the whole time occupied by the passage of a train (when the attendant ought to be minding the brake), it is fitted with two curved iron shoes of such a form as to prevent it from dropping between two tubs (which are apparently not loaded above the level of their sides). The whole apparatus was rigged up in about three-quarters of an hour at a cost of about 2*s.*, and has now been at work for about seven months without giving any trouble.

Mr. Demeure, after remarking that the Dessent system possesses the further disadvantage that there is room for a wagon to slip past between the catches for the up and the down lines, and, although off the rails, to run down the incline, describes a block schemed by Mr. Degueldre, consisting of a bar slung from above by two parallel rods, so that, when drawn to one side by a hand-cord, it at the same time rises clear above the wagons. This arrangement is open to the objection that it will not yield automatically to make way for an ascending train, as the Dessent and Tellier catches do.

Both the Degueldre and the Tellier stops are open to the objection that the attendant, to save himself trouble, may fasten them permanently up; but with the latter, as suggested by Mr. Larmoyeux, this may be overcome by a second swinging bar fixed lower down the inclined plane, and connected to the first by a cord, so that after the last tram has cleared the stop, the first one strikes the second or lower bar, and ensures the fall of the stop.

The Paper is illustrated by engravings of the Tellier, the Degueldre, and the modified Dessent blocks.

W. S. H.

The Action of Powder, Dynamite, and Fire-Setting at Kongsberg.

By J. H. L. Vogt.

(Berg- und Hüttenmännische Zeitung, 1886, p. 365.)

The most important silver mines at Kongsberg, in Norway, are the Gottes Hülfe in der Noth, and the Kongen og Armen mines. The former is worked almost exclusively in very hard hornblende schist, the latter in soft mica schist. The consumption of blasting material is about the same at both mines; but the cost is greater at the Gottes Hülfe mine, because boring a hole in the hornblende takes twice as long, and wears away twice as much steel from the drill as it does in the mica. When powder is employed, the cost and time required at the Gottes Hülfe mine is twice as great in the large working places, as at the Kongen mine, and one-and-a-quarter time as great in the narrow ends. With dynamite the effect is the same in both kinds of rock, and in wide and narrow places. As a rule, it is found that when dynamite is

employed half the workmen can be dispensed with—a workman with dynamite doing double the work of one with powder. The cost at the Kongen mine was about the same with dynamite and with powder, whilst at the Gottes Hülfe mine it was reduced 33 per cent. by employing the former. It must, however, be mentioned that wages were 42 per cent. higher during the dynamite period (1876–1880) than those in the powder period (1866–1870). Dynamite works better in the hornblende schist than in mica schist, and with greater advantage in narrow places than in wide ones.

Fire-setting is still occasionally used at Kongsberg, hornblende schist and quartz schist being well suited for the method. Mica schist, however, is not, since it requires a much greater heat than the brittle hornblende schist. The cost of driving 1 metre of level with fire-setting, and with powder, was as follows:—

	Fire-setting.			Powder.		
	£	s.	d.	£	s.	d.
Kongen mine (1860–1870) . . .	3	13	9¼	4	4	7¾
Gottes Hülfe „ (1866–1870) . . .	3	7	9¼	5	6	0

The cost of driving 1 metre at the Kongen mine (1876–1880) was £4 19*s.* 7*d.* with fire-setting and £3 19*s.* 8½*d.* with dynamite. The cost at the Gottes Hülfe mine (1876–1880) was £3 18*s.* 8¾*d.* with fire-setting, and £4 16*s.* 5*d.* with dynamite. Fire-setting has its disadvantages. The smoke has to be conducted away, the workmen suffer from the heat, the rock is quite unrecognizable, and hand-picking is rendered difficult. It is consequently never employed in rich silver veins, but only in cross-cutting and in exploratory work.

B. H. B.

On the Flow of Gases. By — Hugoniot.

(Annales de Chimie et de Physique, 1886, p. 375.)

The Author is of opinion that Mr. Hirn's experiments on this subject entirely agree with the formulas deduced from the equations of hydrodynamics and form a remarkable verification of them. The following are among the principal consequences he considers to result from Mr. Hirn's experiments. That in ordinary cases the heating of gas during expansion is so slight, that the transformation it undergoes must be regarded as adiabatic. Weisbach's or Leuner's formula of flow, although only rigorously exact for a thread of water, applies with great exactness to veins of finite dimensions. When the ratio of the extreme pressures p_1 to p_0 is greater than 0·522, the vein contracts more and more from the point where the pressure is p_0; its weakest section, therefore, is where the pressure equals p_1. When the ratio of p_1 to p_0 is less than 0·522, the vein after contracting expands, so that a section

of maximum contraction exists in which the pressure is equal to $0 \cdot 522\, p_0$, whatever may be the value of p_1. It is the section of maximum contraction which must always be considered when the delivery has to be calculated. The delivery depends upon the coefficient of contraction, which in its turn does not depend alone upon the form of the orifice, but varies with the ratio of p_1 to p_0 of the extreme pressures, increasing as this ratio diminishes. When the ratio p_1 to p_0 becomes less than a certain limit, the coefficient remains sensibly constant for the same orifice; for orifices cut in the thin sides of a vessel, so long as the ratio of p_1 to p_0 is less than $0 \cdot 3$, and for orifices with conical mouthpieces, so long as it is less than $0 \cdot 5$. The pressure in the contracted section being in this case always equal to $0 \cdot 522\, p_0$, it results that the delivery continues sensibly constant, whatever the final pressure p_1 may be, so long as it is less than the limit in question. If the flow takes place from a conical converging mouthpiece, the variations in the coefficient of contraction are so small that in practice this coefficient may be considered constant and equal to unity, the relative error which can possibly occur in estimating the flow not exceeding 3 per cent. For orifices in the thin side of a vessel the coefficient of contraction varies between $0 \cdot 634$ and $0 \cdot 845$; and for conocylindrical mouthpieces between $0 \cdot 9$ and $0 \cdot 96$.

E. F. B.

The Varied Flow of Gases. By — HATON DE LA GOUPILLIÈRE.

(Comptes rendus de l'Académie des Sciences, vol. ciii. 1886, p. 662, and p. 709.)

The object of this note is to present a complete solution of the problem of the progressive filling of the compressed-air receivers of tramways and locomotives, at the expense of a reservoir maintained by the compressors at a constant tension p_1. The Author first solves the problem generally, and then applies it to the two fundamental examples of isothermal and adiabatic flow. Let t represent the time at the end of which the pressure attains a certain value p; V the volume of the receiver which was originally at the atmospheric pressure p_o, S the section of the orifice, m the coefficient of contraction, g the acceleration of gravitation, v the velocity. Then, for isothermal flow, $p\,v = \mathrm{R}\,(\theta + 273)$, and

$$t = \frac{\mathrm{V}}{m\,\mathrm{S}} \sqrt{\frac{2}{g\,\mathrm{R}\,(\theta + 273)}} \left(\sqrt{\log \frac{p_1}{p_0}} - \sqrt{\log \frac{p_1}{p}} \right),$$

and the total time required for filling is—

$$\mathrm{T} = \frac{\mathrm{V}}{m\,\mathrm{S}} \sqrt{\frac{2 \log \frac{p_1}{p_0}}{g\,\mathrm{R}\,(\theta + 273)}}.$$

For adiabatic flow, $p\,v^k = p_1\,v_1^{\,k}$, and—

$$T = \frac{V}{m\,S}\sqrt{\frac{2}{g k\,(k-1)\,R\,(\theta_1 + 273)}}\log\left\{\frac{p}{p_0}^{\frac{k-1}{2k}}\frac{1+\sqrt{1-\left(\frac{p_0}{p_1}\right)^{\frac{k-1}{k}}}}{1+\sqrt{1-\left(\frac{p}{p_1}\right)^{\frac{k-1}{k}}}}\right\},$$

and—

$$t = \frac{V}{m\,S}\sqrt{\frac{2}{g k\,(k-1)\,R\,(\theta_1 + 273)}}\log\left\{\frac{p_1}{p_0}^{\frac{k-1}{2k}}\sqrt{\left(\frac{p_1}{p_0}\right)^{\frac{k-1}{k}} - 1}\right\}.$$

These equations give the solution of the problem of the flow of air from a reservoir at which the constant pressure p_1 is greater than that of the atmosphere p_o, into a receiver where the pressure gradually rises from p_0 to p_1; the inverse problem is next treated, in which a receiver containing air at pressure p_1 passes freely into the atmosphere at pressure p_0. In this instance the problem of isothermal flow does not allow of integration, but by giving k its generally accepted value of $1 \cdot 4$ or $\frac{7}{5}$, the question may be treated adiabatically—

$$t = \frac{15\,V}{8\,m\,S\sqrt{7\,g\,R\,(\theta_0 + 273)}}\left\{\log\left\{\left(\frac{p_1}{p}\right)^{\frac{1}{7}}\frac{1+\sqrt{1-\left(\frac{p_0}{p_1}\right)^{\frac{2}{7}}}}{1+\sqrt{1-\left(\frac{p_0}{p}\right)^{\frac{2}{7}}}}\right\} - \left\{\left(\frac{p}{p_0}\right)^{\frac{1}{7}} + \frac{3}{2}\left(\frac{p}{p_0}\right)^{\frac{3}{7}}\right\}\sqrt{\left(\frac{p}{p_0}\right)^{\frac{2}{7}} - 1} + \left\{\left(\frac{p_1}{p_0}\right)^{\frac{1}{7}} + \frac{3}{2}\left(\frac{p_1}{p_0}\right)^{7}\right\}\sqrt{\left(\frac{p_1}{p_0}\right)^{\frac{2}{7}} - 1}\right\},$$

and—

$$T = \frac{15\,V}{8\,m\,S\sqrt{7\,g\,R\,(\theta_0\,273)}}\left\{\log\left\{\left(\frac{p_1}{p_0}\right)^{\frac{1}{7}} + \sqrt{\left(\frac{p_1}{p_0}\right)^{\frac{2}{7}} - 1}\right\} + \left\{\left(\frac{p_1}{p_0}\right)^{\frac{1}{7}} + \frac{3}{2}\left(\frac{p_1}{p_0}\right)^{\frac{3}{7}}\right\}\sqrt{\left(\frac{p_1}{p_0}\right)^{\frac{2}{7}} - 1}\right\}.$$

E. F. B.

On a Law of Fresnel. By E. Jablonski.

(Journal de Mathématiques, 1886, p. 441.)

The law in question was formulated by Fresnel as a hypothesis, which enabled him to establish the mechanical theory of refraction. It is this:—The squares of the velocities of propagation of plane waves in two different ethereal media are inversely proportional

to the densities of these media. Or, if δ be the density of free ether, δ' that of ether which penetrates a transparent ponderable body, and r the index of refraction of this body, supposed isotropic, then

$$r^2 = \frac{\delta'}{\delta}.$$

The Author has previously published, in the same Journal,[1] the result of mathematical investigations on the deformations suffered by ether when it penetrates a ponderable body, and has given the means of calculating them in function of the masses of the ponderable particles and of their mutual distances. The formulas give results connected with the structure of the body, and allow, without any further hypothesis, except that of action at a distance, of accounting for the different states of the ether which penetrates a body, according to the different crystalline systems to which this body may belong. There is reason to believe that some laws derived from these formulas are true, but they disagree with the law of Fresnel, and the object of the Paper is to remove this difficulty.

If $\frac{m^2\mu}{r^n}$ denote the principal term, at very small distances, of the function which expresses the mutual action of two particles of ether of mass m, at the distance r, μ being a constant, and if g be another constant depending on the structure of the medium, it has been found that

$$r^2 = (1 + g_1)^{n-1},$$

and that

$$\frac{\delta'}{\delta} = \frac{1}{(1 + g_1)^3}.$$

There should result, in order that the law of Fresnel might be true,

$$(1 + g_1)^{n+2} = 1,$$

and therefore $n = -2$, that is to say, that the mutual action of two particles of ether would increase with their distance, which cannot be.

It might be seen *à priori* that the law in question is in contradiction with the principle of the theory of Fresnel, or of that of Cauchy, namely, action at a distance, the action being greater the less the distance. Cauchy, indeed, obtained, as the expression of the square of the velocity of propagation of transverse vibrations,

$$\frac{4 - n}{2.3.5} \Sigma \frac{m\mu}{r^{n-1}},$$

the Σ referring to all the ethereal fluid. If n be positive and > 1, of which there is no doubt, since the action of the nearest particles

[1] Journal de Mathématiques, May and October, 1884.

is certainly preponderant, the velocity must be greater the smaller the mean distance between the particles of ether, therefore the greater the density; this is the reverse of what the law of Fresnel requires.

Again, if the steps of reasoning, by which he arrived at the equations which give the intensities of reflected and refracted rays, be examined, it will be found that they do not depend on the nature of the vibrating fluid. Hence there is no reason why the consequences should not be extended to a fluid, the particles of which should repel each other according to the law $\frac{m^2 \mu}{r^n}$, even though such a fluid did not exist. Now, as was seen above, the law of Fresnel is not verified if n be positive.

A fourth argument against the law of Fresnel is that, strictly, it is incompatible with dispersion; for, if a ray of white light fall on a piece of glass, there being no dispersion in empty space, all the waves which compose the incident light will have the same rate of propagation before refraction, and acquire after it different velocities, according to their period of vibration, or colour, in the ether within the glass. This ether should therefore have as many different densities as there are colours in the spectrum.

All these reasons lead to the conclusion that the law of Fresnel is incorrect, and the more so inasmuch as it is useless. The Author refers to formulas previously given in the same Journal, relating to double refraction, uniaxial and biaxial, which were established, and subsist, independently of the law. They give all the known laws of those phenomena, the ellipsoid of Huygens, the surface of the fourth degree of Fresnel, &c. In order to remove all doubt, the Author proceeds to give several applications of the general theory of refraction and of reflection.

This theory, as given by Cauchy, and such as Fresnel himself had presentiments of, rests on the principle of the continuity of movement, which may be expressed thus: When one movement is transformed into another, the initial state of that which begins is precisely the final state of that which ends; that is to say, the state of this movement at all points in space at which the transformation occurs.

The general conditions found, when the principle is translated into analytical language, indicate simply the decomposition of the incident movement into another or others, the whole of which are exactly equivalent to the first. From these conditions it can be seen that the total kinetic energy of the new movement in its initial state is the same as that of the first in its final state, at all points on the surface of separation. In either of the movements the velocity at any point is expressed in the same way, by functions ϕ, ψ, χ, and their partial differential coefficients of the first order with respect to t, and to the co-ordinates of the point; now, by the conditions that hold for all points on the surface of separation, these functions and all their differential coefficients of the first order are equal; the velocities are therefore the same. The

particles on that surface are animated by the same movement in either case, consequently the kinetic energy remains the same.

But two cases have to be considered, according as the new movement or its components are to be propagated in a medium of the same composition as the first—reflection, or in one of different composition, refraction. Consider a vibratory movement, which can always be composed of plane-waves. In the first case, the density remaining the same, no change of the initial amplitudes, derived from the general conditions, is required, in order that the kinetic energy of the reflected movement may remain the same at the surface of separation. In the second case, however, the amplitude of each plane-wave must change with the density, so that the intensity may remain the same. In the latter case, the equation of kinetic energies must be brought in, in order to render possible the complete determination of the refracted movement at a point beyond the surface of separation.

The Author first applies the general conditions to the simple case studied by Fresnel, when he enunciated the law in question.

The reflecting surface being supposed plane, the surface of separation is a plane parallel to it, and at a distance comparable to the radius of the sphere of action of a ponderable particle outside the body. It is taken as the plane of the $x\,y$, whilst the outward direction of the normal is taken as the positive direction of the z. I O being the incident ray, the plane of incidence I O z is taken for the plane of the $x\,z$. The vibration is supposed to be polarized, rectilinear, and at right-angles to the plane of incidence, or parallel to O y. Let

$$\xi = 0,\ \eta = \mathrm{B}\,e^{i(ax+cz-st)},\ \zeta = 0,$$

be the components of this persistent vibration, B being the amplitude, a, c, s being real, and i standing for $\sqrt{-1}$. The plane of the $x\,y$ separates two ethereal media, free ether above, ether modified by a ponderable isotropic body below. In each of these, longitudinal and transverse vibrations can be propagated.

Decomposing, in accordance with the principle of continuity, the incident movement into as many as can possibly result from it, namely, a longitudinal and a transverse vibration in either medium, the Author shows that actually it gives rise only to two new vibrations, transverse, persistent, and polarized like the first.

The components of the reflected vibration, in the upper medium, are—

$$\xi' = 0,\ \eta' = \mathrm{B}'\,e^{i(ax-st)},\ \zeta' = 0$$

for $z = 0$. Those of the refracted vibration, in the lower medium, are—

$$\xi_1 = 0,\ \eta_1 = \mathrm{B}_1\,e^{i(ax-st)},\ \zeta_1 = 0$$

for $z = 0$. The relations between the amplitudes are—

$$\mathrm{B}' + \mathrm{B}_1 = \mathrm{B}, \text{ and } \mathrm{B}'\,c' + \mathrm{B}_1\,c_1 = \mathrm{B}\,c,$$

or, in another form—

$$\left.\begin{aligned} B - B' &= B_1 \\ B + B' &= B_1 \frac{c_1}{c} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

And, if δ and δ' be the mean densities of the two media, the expression may be written—

$$\delta B^2 I \cos a = \delta B'^2 I' \cos a + B_1{}^2 \frac{I^2}{I_1{}^2} \frac{\delta}{\delta'} I_1 \delta' \cos a_1,$$

or, putting b_1 for $B_1 \frac{I}{I_1} \frac{\sqrt{\delta}}{\sqrt{\delta'}}$,

$$\delta B^2 I \cos a = \delta B'^2 I' \cos a + b_1{}^2 I_1 \delta' \cos a_1 \quad . \quad . \quad (2)$$

which means, that the kinetic energy of the incident wave is equal to the sum of the kinetic energies of the reflected wave, and of the refracted wave of amplitude b_1.

In the theory of Fresnel, b_1 is supposed to be equal to B_1; the first of the equations (1) is established directly, as also equation (2), whilst the second of the equations (1) is a consequence of (2).

The present theory gives the two equations (1) directly, and if B_1 be supposed to equal b_1, it follows that $\frac{I}{I_1} \frac{\sqrt{\delta}}{\sqrt{\delta'}} = 1$, or, w and w_o being the velocities of propagation in the lower medium and in the free ether respectively, $\frac{\sqrt{\delta}}{\sqrt{\delta'}} = \frac{w}{w_o}$, which is precisely the law in question.

The equations (1) have been established without any hypothesis as to the law which connects the velocities and the densities, nor as to the law of mutual action of fluid particles; but if the amplitude B_1, calculated by means of these equations, and for every point on the surface of separation, be supposed to remain unchanged, when the corresponding wave is propagated in the lower medium, the law of Fresnel must be accepted, which it cannot be for the reasons given above. Hence the hypothesis to be rejected is that which Fresnel implicitly made, namely, that $b_1 = B_1$.

The amplitudes B' and B_1, at all points on the surface of separation, are obtained from equations (1), in conformity with the general theory. That of the reflected vibration remains the same for all points, the medium being unchanged; but equations (1) are not sufficient, and that of the kinetic energies, (2), must be added. From it is obtained, $b_1 = B_1 \frac{I}{I_1} \frac{\sqrt{\delta}}{\sqrt{\delta'}}$, b_1 being the amplitude of the refracted wave at all points in the lower medium.

Treatment of the case in which the vibration is in the plane of

incidence leads to two equations that must hold if Fresnel's implicit supposition be correct, but one of these equations is incompatible with the other.

Similar results are obtained from the consideration of the general case, in which the vibration is unrestricted.

In the case of a double-refracting body, the transverse refracted vibrations advance with different velocities in different directions. The law of Fresnel applied to these rays would imply that the mean density of the ether, within one of the cells formed by the ponderable particles, varied with the direction around the centre of that cell. It is shown, by an example, that this is not so.

The Author holds, that the only way of escaping from all the difficulties raised by a thorough examination of the question, is to reject the law of Fresnel, and that this can be done without any breach of the general principles of mechanics.

A. B.

Electric Lighthouses in France.

(Report of the Special Nautical Commission appointed by decision of the French Minister of Public Works, 24 November 1885.[1])

The Commission was composed of Captain Fleuriais, President; Mr. Bourdelles, Engineer-in-Chief of the Ponts et Chaussées, charged with the service of inspection of lighthouses; Mr. Caspari, hydrographical engineer, Reporter; and Captain Lefèvre, Commander of the "Coligny." It visited in turn Dunkirk, Boulogne, and Calais, and heard what the sailors, captains of merchant ships, packet boats, and coasting vessels, and the fishermen, pilots, and harbour-officers, had to say, to the number of forty-eight persons in all. A sub-commission verified this evidence by an excursion at sea on board of the "Coligny."

The only electric lighthouses in France in the year 1880 were the twin lights of La Hève, and the Gris-Nez light, established in 1863 and in 1869 respectively. Six electric lighthouses were then in operation in England, and two in the rest of the world. In 1880, Mr. Allard completed his memoir on the subject, proposing a complete programme for the illumination of the coasts of France by electricity. In 1825, the Commission of Lighthouses adopted this principle: "When a vessel following the coast in ordinary weather begins to lose sight of the important landfall light it has passed, it should see the one towards which it is approaching." This condition was fulfilled by the oil-lights existing in 1880 during half of the year. In order to fulfil it during five-sixths of the year, Mr. Allard proposed forty-two scintillating electric lights, distinguished by the number of flashes (1 to 4) per group, succeeding groups being separated by a lengthened eclipse, or by a

[1] A copy is in the Library, Inst. C.E.

red flash. This programme was approved of in December, 1880, and a beginning was made in the English Channel.

A quadruple-flashing light was inaugurated at Calais in October, 1883; a triple-flashing light with a red flash between the groups at Gris-Nez in September, 1885; a double-flashing light at Dunkirk in October, 1885. The power of these lights corresponds to a minimum range of $19\frac{1}{10}$ miles during five-sixths of the year, and of $43\frac{3}{4}$ miles during one-half of the year. Twin fixed electric lights were inaugurated at La Canche in October, 1884, the power of which corresponds to a range of 33 miles during one-half of the year. To complete the list of existing electric lighthouses there remain: the twin fixed lights of La Hève; scintillating lights at the Baleines and at Planier; a special light at Palmyre.

The French Report quotes the conclusions of the report published in 1885 by the Trinity House, but observes, as was stated in the latter, and as confirmed by French statistics, that the weather was exceptionally clear in the year during which the English experiments were made, and that, as the observations in England were on fixed or slowly-revolving lights, they may not be in all respects applicable to the French fast-revolving lights. In presence of these circumstances, and of the delay in further adoption of electric lighthouses in England since 1880—one new station only, Saint Catherine's Point, being projected—Mr. Leferme, Director of French Lighthouses, proposed in October, 1885, that a nautical inquiry should be made into the performance of the Channel electric lighthouses. The special questions placed before the nautical commission were:—

"Whether it be expedient to renounce characters of slow-revolving lights, and even of fixed lights, and to employ exclusively scintillating lights, with groups of flashes separated by a long eclipse or by a red flash;

"Whether this flash is in some respects unsuitable, and whether first intentions as to its employment should be modified;

"Whether it would be expedient to slacken, to an extent to be determined, the speed of rotation of existing apparatus."

Results of the Inquiry.—Whilst the "Coligny" approached the electric lights, they were picked up far beyond their geographical range—Gris-Nez at 44 miles, Calais at 38 miles, and Dunkirk at 36 miles. On the return voyage from Dunkirk to Cherbourg, when the weather was squally, with rain and hail, the lights disappeared at the limits of their geographical ranges. "More than once in the evening," said Captain Lefèvre, "the Gris-Nez light, distant 12 or 14 miles, almost entirely disappeared in a squall: its flashes were still visible, however, each in turn lighting up the rain, and appearing like a faintly-lighted globe. I doubt whether an ordinary light would have continued to be visible in like conditions." Sailors in general affirm that the new lights are better than the old ones, even during haze. The superiority of electric light during haze or rain is attributed to its momentary illumination of the clouds. The succession of glimmers and

eclipses allows of recognizing the light, even when it is not seen directly. From the anchorage at Dover, Gris-Nez light, distant 18 miles, is said to appear quite near; and Calais, distant 22 miles, is visible, but on some days the glimmers of it only are seen. In fine weather, fishermen pick up the lights at a distance of 40 miles, seeing the glare on the horizon long before the light proper, and making out the succession of flashes and eclipses. In such weather an increase of from 20 to 25 miles in range is attributed to the lights. Approached from the north, Dunkirk is seen before Ruytingen, but in light haze it becomes visible only at 7 miles. A pilot has seen Gris-Nez at 3 miles in haze. In thick haze the illumination of the fog by the Calais light is seen at the end of the breakwater, which was not the case for the oil light. These results agree with previous experiments in France, and with those of the English Committee. Thus although the aim of the programme is not fully realized, the evidence shows that *electric lights have greater illuminating power than oil lights for all weathers and at all distances.*

Characteristics of the Lights.—Flashing suits the variable nature of electric light better than fixed beams. The latter may be mistaken for ship's lights; this objection is so far removed by using twin fixed lights. Still, it is thought desirable to substitute a single flashing light for the twin fixed lights of La Canche, whose intensities have been found unequal, and which, having been mistaken for the South Foreland lights, have caused vessels to run ashore.

A number of observations on the Gris-Nez light, in which a red flash separates groups of triple-flashes, indicate that the proportion of light given to the red flash, namely four and a half times that given to a white flash, is insufficient, when the luminary is electric. The figure four and a half rested on experiments made by Mr. Allard at distances not exceeding 10 miles. This defect in the Gris-Nez light is not dangerous, however, its triple flash distinguishing it from all its neighbours. When the electric arc is replaced by the flame of the reserve oil lamp, the red flash appears more intense than the white flashes.

Dazzling Effects and Speed of Rotation.—In regard to the first of these questions, the evidence is of a conflicting nature. Some persons consider that rapidity of rotation increases the dazzling effect. The English Report does not distinguish between this effect as caused by a fixed or by a flashing light. A master-fisherman has described picturesquely his impressions of the Calais light: "At first the rays dipped too much, it was terrible; when still far from land one seemed to be quite near. It was very dangerous. At 1½ mile from the jetty, the glare falling upon the water made it appear as if the sea had become suddenly rough. The dip of the rays must certainly have been changed about three months after lighting; since the light has been raised the installation is perfect." This testimony is considered valuable, as depicting the troubling effect caused by sheaves of electric light

sweeping through space; also in giving an approximate figure for the time required by a local sailor to become accustomed to the new light. No change had been made on the light. Further, the Captain of the Port of Calais has returned from his first unfavourable impression, stating that the new light "illumines the approaches of the harbour, the channel, and the tidal quay, sufficiently to prevent collisions, even when the boats are without lights. Navigators become familiarized to its action."

At Dunkirk, opinion is unanimous as to troublesome dazzling effects when ships enter from the roads; these are aggravated by the rapid succession of the flashes. Mariners demand the separation of the flashes by an eclipse of twenty or thirty seconds to allow of ships in the roads being seen, and that the amount of dip be diminished. At the time the inquiry was made, however, the Dunkirk light had only been in operation for six months. The captain of the "Coligny" found the light troublesome in coming to anchor among other boats lying in the roads. At a distance of 6 miles, when the reserve lamp was substituted for the electric lamp, the harbour lights, previously dim, stood out clearly. The results of the inquiry show, however, that trouble need not be apprehended from feebler lights being overshadowed.

The taking of bearings is facilitated by the rapid succession of flashes, and the angle between an electric light and another, at unequal distances, can easily be observed with the sextant, if the less brilliant light be looked at directly. Fishermen find the new light more helpful for lifting nets than the old one, in which the eclipses were longer. The captains of the English steamers plying between Folkestone and Boulogne prefer rapid to slow flashes. The fixed lights at the South Foreland eclipse the position lights of a crossing vessel, whilst at Gris-Nez a ship's lights become visible during the eclipses of the electric light. Sailors like the rapid flashes, and are struck by the convenience of recognizing a light by simply counting the number of flashes in a group. The manner in which rotating sheaves of light stand out against the sky, lighting up the air and clouds, is a useful quality. Difficulty in estimating distances from an electric light should be met by taking bearings.

Working Performance.—Serious inconvenience has been caused by the hard crystalline dust, arising from the combustion and bursting of the carbons, entering the pivots of the revolving-carriage rollers and of the toothed wheel-gearing. This occasions frequent cleaning and great difficulty in the maintenance for the keepers, who are not clockmakers.

Reserve Lamp.—The reserve oil-lamps can be substituted for the electric lamps in one minute, but their effect in all cases has been so completely to change the character of the light, it becoming almost impossible to discern the separate flashes of a group, and the intensity being so greatly reduced, that a temporary extinction might, it is thought, cause less inconvenience.

Double Light.—On account of the regulators becoming unduly

heated, when two machines were used, it was resolved to postpone a decision on this question.

Summary.—Electric lighthouses perform their function perfectly; any imperfections of detail that may remain escape the notice of sailors. Fixed electric lights should not be used. Sailors are most favourable to scintillating characters, and these give to electric lights their superiority in rainy weather, and when they are picked up beyond their geographical range.

The progress as to range is appreciable, although less than was anticipated by Mr. Allard. In haze the gain is less than was expected, but in foul weather with rain the improvement is decided, and this is the most dangerous condition, since manœuvring is then restricted. In clear weather the lights are splendid, and afford valuable security to sailors.

Near harbours the dazzling effect of electric light is a defect. The relative weakness of red light, liable as it is to cause serious mistakes, furnishes grounds for dispensing with it entirely. The resulting diminution of the number of characteristics will not matter in France, if the original programme be notably diminished.

Electric light should therefore be scintillating, and its use limited to important landfalls.

By a different route the Commission arrives at the same conclusions as the English Committee, from which agreement great confidence is placed in their accuracy.

In consideration of the gain in speed of large ships which has been made since 1825, when the principle already cited, on which depends the choice of sites for outstanding lighthouses, was adopted, and of the greater precision as to position and time of a ship's approach to land than now prevails, the points chosen for landfall lights may be fewer, but should receive lights of longer range.

Experience has shown that the superiority of electric lights is greatly reduced in foggy weather. Hence in foggy districts like the English Channel, an increased number of lights of shorter range would be more useful than widely separated lights of great intensity.

Besides the new lights proposed, as below, for the coasts of France, it is hoped that the Trinity House will include the Casquets among their stations for electric lighthouses. A similar remark applies to Cape Creux, which belongs to Spain.

Conclusions and Opinions.—To sum up, the Commission formulates the following opinions:—

The disposition of electric scintillating lights inaugurated by Mr. Allard, and applied on the coast of France, has advantages over all other systems of illumination employed hitherto in France or elsewhere.

It seems to be almost faultless, optically and mechanically, and as nearly perfect as possible in the present state of knowledge.

It may therefore be adopted, without modification (until further orders) in future installations of electric lighthouses in France.

It will be expedient, however:—

1. Not to use the reserve oil-lamp until means have been found of making it maintain distinctly the characteristic of the electric-lamp.

2. To reduce to a minimum the dust from the burning carbons, and to protect from it the mechanism of the electric-lamps, and of the revolving machinery of the optical apparatus.

3. To renounce the use of double power, until improvements of the apparatus allow of resorting to the ensuing increase of luminous intensity, which indeed is of little practical use.

4. To avoid, especially for landfall lighthouses, the introduction of a red flash among white flashes.

The development of electric lighthouses should be carried on, in the first place, by their establishment at important landfalls, and in the order of importance of these for navigation, namely: Ouessant, Belle Ile, Barfleur, Mouth of the Gironde, Ile d'Yeu, Penmarch.

Before proceeding further, the results of experience to be furnished by these lights should be awaited.

In regard to existing lights, there are grounds for:—

1. Maintaining as at present the scintillating lights, and awaiting further experience before taking measures to obviate the inconvenience of dazzling remarked at Dunkirk and Calais.

2. Substituting a single scintillating light for the twin fixed lights at La Canche.

3. Adopting the same solution for the lights of Havre when the moment for renewing them shall arrive, installing however a small oil light to mark the direction, which they at present indicate so usefully to navigation.

The Report is dated the 15th of June, 1886, and is signed by the members of the Commission already mentioned. It is followed by an Appendix, entitled "Study on the Range of Electric Lights," and signed by Mr. Caspari.

A. B.

On the Employment of Cofferdam in Voltaic Batteries.

By André Reynier.

(L'Electricien, 1886, p. 708.)

Dry or, as they should more correctly be termed, moist elements are specially adapted for purposes of transport, where reduction in gross weight and non-liability to fracture are requisite qualities, for the attainment of which saw-dust or some such absorbent material saturated with the exciting liquid is usually introduced between the electrodes. The requirements for this material are: great power of absorption, low specific gravity with feeble resistance to the electric current, and absence of chemical action on the imbibed liquid. No materials hitherto applied can be considered

to fulfil the above conditions in any satisfactory way, whereas cofferdam apparently does. The substance proposed for this special purpose is different to what has been previously supplied for putting on plates in naval architecture, and is in fact made from the waste produced in the manufacture of that article from cokernut fibre; this by-product being subjected to further treatment until the final result is a pulverulent material of the appearance and colour of ground cocoa, and termed by the inventor, Mr. Germain, "sporique." Its density is about 0·08, and by simple pressure in the hand the volume can be reduced by two-thirds; while its absorbing power is greater than that of any known substance, as it will imbibe 12·5 times its weight of water. For use in electric batteries, however, the sporique is allowed to fix only seven times its own weight of liquid, and this constitutes what is termed the "standard paste." The mechanical action in absorption is quite different to that of most similar substances, so that it must be forced by heat or other means to imbibe the liquid, which is, however, then held with considerable force, so that the paste is not liable to drip; it is likewise a very bad conductor of heat, thus retarding both evaporation and congelation of the liquid, and is very insoluble in the majority of either acid or alkaline solutions.

The Paper closes with a detailed description of various portable elements of the Leclanché type, in which the liquid is fixed by this material.

F. J.

The Electric Subway Conduit in New York.

(Scientific American, vol. lv. 1886, p. 224.)

This conduit is being made from prismoidal blocks, 3 feet in length, pressed from a compound of bitumen with 30 per cent. of hot sand. These blocks are formed in iron moulds traversed by mandrils, which shape the longitudinal holes destined to receive the wires; the compound, previously mixed, is fed in small quantities and intermittently machine-rammed until the sound proves it to be solid; at either end of each hole is a slight enlargement, into which fits a short paper tube for the completion of the pipe at the junction of block to block.

In laying the conduit the blocks are carefully aligned on a concrete bed, and the joints made as follows: the block is carefully lowered and placed about 1 inch from the one already set, a hot iron plate is then introduced into the vacant space until the two faces are thoroughly hot, after which the paper tubes are entered, and wooden mandrils passed through the holes from the open end, the block is then pressed home until the tubes are properly seated; an iron frame is clamped round whatever opening is left, and hot bituminous mixture worked in with heated iron bars, the clamps

being removed after the joint has cooled. The whole surface is further covered with a course of brickwork. At each cross-street a bricked man-hole with iron cover is interposed, at which the necessary junctions and introductions of wires can be effected. In New York twenty-four pipes are being provided, the blocks, as above described, each having twelve holes and being laid in two parallel lines.

In Brooklyn the apertures are ten in number and of smaller diameter, while the joints are made without the paper tubes, a flange being provided at one end of the block as in the ordinary water- or gas-pipes.

The connection with the houses along the route is to be effected by a branch carried from the nearest man-hole to the centre of each block of buildings, from whence the circuits will be completed by ordinary overhead or underground wires.

While cheapness of construction is thus obtained, many good qualities of metal pipes are lost; thus the inner surface of the holes can hardly be so smooth, and may possibly alter in shape with lapse of time, while the anti-inductive effect, introduced by the use of metal pipes, will have to be supplied by the leaden or other covering of the individual conductors. Any objection to metal pipes, on the ground of their liability to decay, can hardly be considered as justified by experience.

F. J.

Influence of Current Density on the Resistance of Wires.

By HANS GÖTZ.

(Centralblatt für Electrotechnik, 1886, p. 309.)

The Author describes a series of experiments made to determine the existence and effect of the above influence, as until now contradictory opinions have been put forward on this point. He strives to show by these experiments that the resistance of a wire is either increased or decreased according to the current-density. For the measurements, a Wheatstone bridge and mirror galvanometer were specially arranged, so that the resistances could be estimated within 0·00002 Siemens unit, and to avoid influences of temperature the wire under test was laid parallel to an exactly similar comparison wire in water, which was well stirred before each measurement. In each case the current was passed through the wire for a period of twenty minutes, and the resistance ascertained before and after. The kinds of wire used were hard and soft copper, and hard and soft German silver. To learn the effect of the direction of the current upon the resistance, a current was passed first in the one direction, then in the other, and then again in the original direction.

The results of the experiments show that the following effects occur:—

(1) With hard copper wire the resistance sinks at first, and then, with increased density, reaches its original value, and with a still greater density exceeds it.

(2) Soft copper wire has at first more constant resistance, increasing only with the greater densities.

(3) Hard German silver wire behaves similarly to hard copper wire.

(4) Soft German silver wires show, in general, no clear tendency to either increase or decrease in resistance.

(5) Solid conductors suffer, from the passage of large currents, a sort of polarization, because the resistance increases when the current is passed in the one direction, and sinks again on its being passed in the other, and on again passing the current in the original direction, a further and somewhat larger increase in resistance is the result.

E. H.

On a New Method of Determining the Coefficient of Expansion of Solids. By R. Weber.

(Comptes rendus de l'Académie des Sciences, vol. ciii. 1886, p. 553.)

If a solid body is made to oscillate in vacuum like a pendulum, the period of the oscillation depends on the form and mass of the body, and the distance of the molecules from the axis of rotation. At two different temperatures the distances of the molecules from the axis of rotation are different, whence results a different period of oscillation. In other words, there is a determinate relation between the temperature, the dimensions, the period of oscillation, and the coefficient of expansion; the three former being determined experimentally, the latter may be calculated. The Author hopes soon to give the results of some experiments.

E. F. B.

On the Intensity of the Magnetic Field in Dynamo-Electric Machines. By Marcel Deprez.

(Comptes rendus de l'Académie des Sciences, vol. ciii. 1886, p. 712.)

The magnetic field consists of two elements, the volume and the intensity, which in different degrees constitute its useful qualities. Neither the globe, a vast field of low intensity, nor the opposite poles of a powerful electro-magnet brought almost into contact, can be usefully applied. The Author, considering the impossibility of solving the problem of the intensity of the magnetic field theoretically, has undertaken a large number of experiments under varied conditions. He employed electro-magnets of

three different sizes, of which the iron cores were respectively 200 millimetres (7·9 inches), 90 millimetres (3·6 inches), and 60 millimetres (2·4 inches) in diameter, and in each the intensity of the field was measured, comprised between the opposite poles of two identical electro-magnets, both excited by the current, and between the poles of the electro-magnet, and an iron armature submitted to its influence.

The intensity of the field was calculated by measuring the effort exercised perpendicularly to the lines of force on a movable conductor traversed by a known current. The dimension of the field taken in the direction of the lines of force, that is to say, the separation of the magnetic surfaces between which it is comprised, and perpendicularly to the direction of the lines of force, or the magnitude of the polar openings, as well as the intensity of the current traversing the magnetizing helices, were all varied.

As regards the influence of the separation of the magnetic poles, the Author finds, contrary to general opinion, that the intensity of the field diminishes much less quickly than the distance of the magnetic poles increases. Thus the intensity only diminished one-half, when poles originally 7·5 millimetres (0·3 inch) apart, were removed to 75 millimetres (3 inches) apart. When the field is comprised between a magnetic pole and an iron armature magnetized by its influence, the diminution of the intensity corresponding to the increase of the distance is more rapid, but instead of its diminishing as the inverse square of the distance, it is more nearly as the inverse square root. Thus, when the distance increases from 1 to 4, the intensity of the field diminishes from 1 to 0·6. By bringing the poles very close, the intensity of the field is very slightly increased, whilst the space available for the induced wire is reduced almost to zero. There is a certain dimension of the annular space between the magnetic poles and the revolving armature which brings about a maximum efficiency; when the dimensions of the machine, its velocity of rotation, and the electro-motive force it should produce, are given, the efficiency will be highest when the interior resistance of the ring is a minimum. If x represent the annular space taken in the direction of the radius, a the minimum space for everything but the copper placed round the ring, and H the intensity of the field, then the internal resistance of the machine is a minimum, when the function $H^2 (x - a)$ is a maximum.

The value of a is much higher for high-tension machines than for those of low tension.

With reference to the influence of the dimensions perpendicular to the lines of force, the Author has made but few experiments, but has succeeded in proving that, unless the polar pieces are very thick in the direction of the lines of force, the intensity of the field is sensibly in the inverse ratio of the surface developed from the expansions taken perpendicularly to the lines of force.

E. F. B.

On the best Disposition of Electrodes in Electrolytic Experiments.

By ADRIEN GUÉBHARD.

(L'Electricien, 1886, p. 674.)

In his description of the best method for the electrolytic calibration of galvanometers, Mr. T. Gray [1] recommends a plane anode between two parallel cathodes of somewhat larger dimensions. The Author claims that this, though superior to some arrangements usually employed, is only an approximation to what his researches in this direction demonstrate as the disposition that should always be adopted, viz., that the electrodes should coincide with equipotential surfaces in the liquids in which they are plunged. The simplest case would theoretically be that of two concentric spheres, or for practical reasons, hemispheres; but perhaps the best, taking all things into consideration, would be two concentric cylinders with their axes vertical, the lower edges being hermetically closed with some insulating substance.

The arrangement adopted by Mr. Gray would be improved by bending the cathodes so as to form the surface of an elliptic cylinder, while the geometric projection of the anode would be the line joining the foci of the ellipse.

F. J.

Atmospheric Electricity and the Weather.

By Captain C. v. BERMANN.

(Mittheilungen aus dem Gebiete des Seewesens, 1886, p. 457.)

Although numerous observations in recent years of the phenomena of atmospheric electricity have enriched our knowledge of it, they have but increased the number of hypotheses as to its origin. The Author agrees with those who compare our atmosphere under the influence of solar heat to an Armstrong hydro-electric machine, the air being the surrounding insulator, the earth, in normal circumstances, the inductor, the clouds the receptor. Atmospheric electricity would thus arise from the circulation of air-currents kept up by solar heat.

After enumerating several facts concerning atmospheric electricity, the Author proposes the question, whether the present incomplete knowledge of it justifies the assumption that observations of its condition would furnish valuable criterions of the weather. He would answer in the affirmative. Since temperature, humidity, and wind affect its condition, the possibility of returning from it to them is evident. Observations made in Switzerland, with a Mascart

[1] Paper read at British Association Meeting, 1886.

electrometer, showed that the curves of atmospheric electricity were connected with the weather. In clear and bright weather they were constant and characteristic. The Author cites a number of facts, such as, that electrical changes occur an hour before barometrical changes, that the positive tension of atmospheric electricity appears to increase twelve or fifteen hours before the outburst of storms, and others, in confirmation of the belief that the electric condition of the atmosphere merits observations for weather-forecasting, as much as do pressure, humidity, &c.

In order to learn from continuous observations how far the principal elements of meteorology take part in changes of the electrical state of the atmosphere, the Author uses results observed at Greenwich, with a Thomson self-registering electrometer, in the four years, 1880 to 1883. Assuming that the magnitude of electric potential varies directly as the humidity and current-motion, or wind, of the atmosphere, and inversely as the temperature and pressure, comparison of the electric curve with those of the four elements just named, confirms the assumption most perfectly in regard to temperature, next as to wind, then as to humidity, and lastly as to pressure. On account of the want of absolute accuracy in the indications of an electrometer, and of other deficiencies, the results of these comparisons may not agree with observations made with better instruments, but the Author holds them to be so far relevant. Supposing the order of agreement between the assumption and the observed results to be correct, it might be concluded that, disregarding the influence of temperature, a change of potential would in the second place point to a rise or fall of wind. And if the influence of pressure be as slight as was found, there should then be two independent factors for judging of the weather. Great importance is attached to indices of an element so important at sea as wind.

In order to take full advantage of electricity meteorologically, a vast number of observations are necessary, such as Humboldt and Dove had at their disposition in determining isothermal lines, and such as Maury had for oceanography. The Author would consider the aim of his Paper fulfilled if he should have shown the desirability of an outlay of £10 or £20 per ship, for the instalment of a practical form of electrometer easy to read. An additional means of foretelling the weather would be valuable on land, but at sea, where the mariner is so often left to his own resources, it would be invaluable. For example, timely warning might have saved five large ships, which fell a prey to a hurricane, in June 1885. The barometer alone as a weather gauge is insufficient, often remaining indifferent on the approach of storms, and showing only a slight jerky rise and fall during the same. This want would be in a measure supplied by the use of an electrometer.

A. B.

Girard's Integraph. By R. GIRARD.

(Il Politecnico, 1886, p. 209.)

This is an instrument for determining the numerical value of the integral $\int_{x=a_1}^{x=a} f(y)\,dx$, whatever may be the form of $f(y)$, y being any function whatever of x. Among the many applications of the instrument are the measurement of the area and the moment of inertia of a figure, the finding of the centre of gravity of a plane figure, and the volumes of many special solids.

Two parallel bars of a brass frame act as guides, upon which travel the four wheels of a trolley, which carries two rods connected at the ends by cross-pieces, and moving between rollers in a direction at right angles to the guides. Between these two rods lies a third (A), of an inverted V section, which projects above the plane of the other two, and carries at one end a pointer. It will be seen that by moving the rods backwards and forwards between the rollers, and the trolley along the guides, two motions at right-angles to one another are obtained, and the pointer can thus be moved into any position and passed over the outline of any plain figure of suitable size. A solid, B, formed by the revolution about the axis of y of a curve having the equation $x f(y) = k$, k being a constant, is made of gun-metal, and set in bearings carried by vertical bars fixed to the frame of the instrument. These bearings slide vertically between the bars, and the solid can therefore move up and down, its axis being always maintained in a horizontal position parallel to the guides of the frame, and can at the same time revolve upon its axis. Some point of the surface of this solid is constantly in contact with the upper edge of the bar A, which, as will be seen, is at right-angles to its axis. As the trolley moves along the guides carrying A with it, the solid B moves up and down, and as A slides backwards and forwards at right-angles to the guides, B rotates on its axis. At one end of the axis of B is a dial with a vernier, by which the readings of the instrument are taken.

The mathematical theory of the instrument is given in the Paper, and the method of applying it to finding the contents of cuttings and embankments.

W. H. T.

Wood-Pulp and its Uses. By M. L. DEERING.

(Journal of the Association of Engineering Societies, October 1886, p. 444.)

The principal uses of wood-pulp are for the manufacture of newspaper stock, fine printing-paper, wall-paper, water-pails, tubs, wash-basins, ink-bottles, boats, observatory domes, and gunpowder. The woods generally used for the manufacture of pulp are: poplar, white pine, yellow pine, spruce, and cotton-wood, the last yielding

the best pulp. The logs are sawed into billets 1 foot long, and the bark is stripped off. The billets are boiled in order to extract the sap, ground, and digested in a vat with linen stock, jute, or other material, to give tenacity. Clay is added for weight and consistency, and sizing is necessary.

Mr. Deering, in 1879, decided to make seamless barrels of wood-pulp, and after six years' of research and experiment, he concluded that this substance was one of the most discouraging to manipulate that has ever been treated by the engineer. The first difficulty was to regulate the shrinkage in drying by artificial heat, which was very variable; occasionally the chimes and the head would draw apart. The drying-oven was raised in temperature very slowly from 100° to 250° Fahrenheit. Small barrels under this treatment came out sound and true, hard and solid as a rock. But on pouring water into them it soaked through everywhere. By soaking the barrels in a varnish of resin dissolved in naphtha, and enamelling the interior by treating the inside with a bath of oil-excluding compound, they were made oil-proof and water-proof.

Full-size oil-barrels of 52 gallons capacity are made in from ten to fifteen minutes. The mould which forms the barrel has a compound revolving motion, at the rate of 40 revolutions per minute, the frame carrying the mould revolving on a horizontal axis, whilst the mould revolves on bearings at right-angles to the axis of the frame. "In short, the barrel was turning round, and at the same time it maintained a circular movement end over end." The mould is filled with pulp from a tank above; then the former, a device for determining the thickness, is inserted and expanded, making the bung-hole. The machine is then set in motion, and after the first half turn, water from a reservoir filled with air and water, under a pressure of 300 lbs. per square inch, is admitted into the barrel in course of formation, and maintained there for a minute and a half. This water is supplied to take the place of that disposed of by centrifugal force, through the mould which is perforated. Air under pressure is then substituted for water for two and a half minutes, after which the machine is stopped, and set with the bung-hole downwards, through which the loose pulp and water within are expelled by the confined air and returned to the supply-tank. The machine is again set in motion, water again admitted, the machine stopped and inverted, and this operation is repeated. The former is removed, the mould is opened, and the fully-formed barrel taken out and dried for thirty-six hours in an oven at 250° Fahrenheit. It is then vulcanized in a solution, chiefly of sulphur and oil, at a temperature of from 400° to 550° Fahrenheit. A barrel of 52 gallons, ¾ inch thick, fresh from the machine, weighs about 75 lbs.; when thoroughly dry, from 30 to 35 lbs.

In conclusion, the Author adds that whilst he made a perfect seamless barrel, uniformity of strength was wanting, some of them not being strong enough to withstand the hard usage incident to transportation.

D. K. C.

The Use of Coal as a Protection against the Fire of Rapid Firing and Machine Guns.

(Mémorial de l'Artillerie de la Marine, 1886, pp. 17–52.)

The object of the experiments undertaken by the Gâvre Committee was, (1) to determine the resistance to penetration of a layer of coal in lumps, in bags of 112 lbs. weight, and in bricks 1·18 inch by 0·78 by 0·39 inch; (2) the degree of protection furnished to ships' decks by the use of a layer of coal in lumps, or bricks; (3) the protection afforded by a layer placed between the outer plates and one placed inside.

The guns used were the 37- and 47-millimetre revolving cannon, and the 47-millimetre rapid-firing gun. The angles of fire varied from 10° to 30°.

As a result of the first experiment it was found that a layer of 19·6 inches was too little to resist the fire of any of the guns; 39·37 inches would arrest a 37-millimetre projectile, but not a 47-millimetre; 59 inches will stop 37- or 47-millimetre shells weighted or charged; but 47-millimetre steel shells weighted are rather too powerful, and it is probable that 47-millimetre rapid-firing guns would penetrate; 62·5 inches will keep out any revolver gun projectile, and 78·75 inches will afford good protection against all machine and rapid-firing guns. The second experiment showed clearly that sacks of 1 cwt. of coal form a slightly better protection than bricks regularly arranged; that steel shells, weighted, gave a greater penetration than chilled iron, and 47-millimetre iron shells frequently broke up in passing through the coal. Loaded shells bursting in coal cause less havoc than weighted ones, except when fired in salvoes with concentrated aim, when revolving cannon projectiles penetrate more easily than before. Tables formed from data ascertained in the first and third experiments show various thicknesses of protective works differently arranged, and giving the best resistance to perforation. After pointing out anomalies in these Tables, new Tables more conformable to reality are given.

It was proved by the second experiment that a layer of coal on a plate 0·118 inch thick cannot be pierced at about 328 feet; even at a distance of 13 feet the resistance to salvoes of charged shell from the 53-millimetre guns (or at 14 feet 6 inches with 47-millimetre shell), was considerable. From these results it is considered that, having regard to the short time of exposure of two ships when passing one another, a layer of coal, disposed as in the experiment, will protect ships from the fire of 37- and 47-millimetre guns.

The final conclusions are: (1) that sacks of coal stowed vertically 59 inches to 78·75 inches thick will afford good protection against the fire of machine and rapid-firing guns; (2) that a single layer about 1 foot thick is enough to protect decks from the fire of machine guns in the tops of other ships.

J. H. R. W.

INDEX

TO THE

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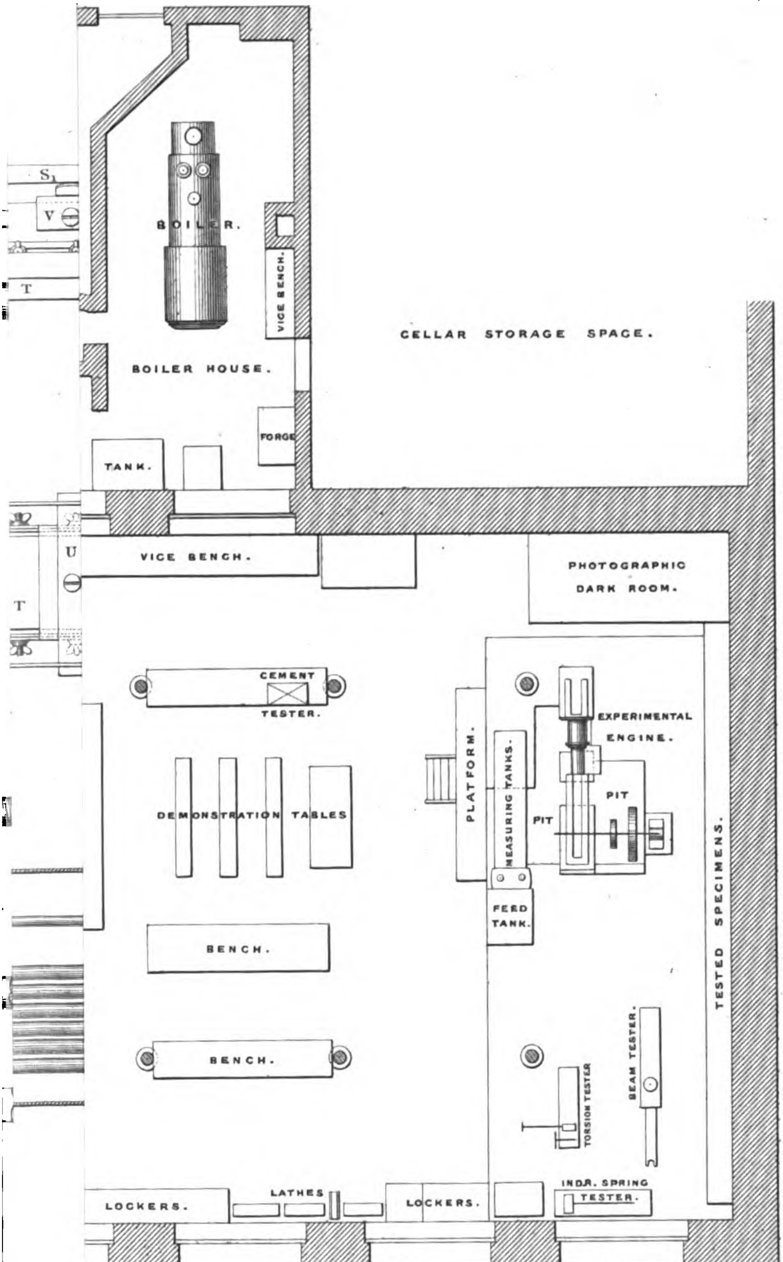

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